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The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT 1957

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1956 to 30th September, 1957

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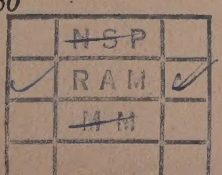

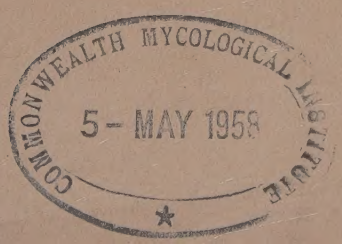

Published April 1958

A41

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(FORTY-FIFTH YEAR)

1957

EAST MALLING
RESEARCH STATION

Near MAIDSTONE

KENT

1st October, 1956 to 30th September, 1957

Published April, 1958

The correct abbreviation of the title of this Report is :—
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* Recognized Teacher of the University of London.

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‡ Also **Fruit Storage Investigations** (in collaboration with Ditton Laboratory).

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M. Cole.

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J. Denyer (37).
E. Wenham (37).
H. Crittenden (34).
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W. Jenner (31).
J. A. Brooker (28).
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Accommodated at East Malling Research Station

Telephone : West Malling 2418.

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Clerical Assistant : Mrs. D. Nye. (*Part-time.*)

GENERAL DEVELOPMENT AND ACTIVITIES

In presenting this Forty-fifth Administrative Report of the Executive Committee, we have again tried to be brief. What have been the principal events of 1957 ? The visit of the Duke of Edinburgh, the surprisingly enthusiastic attendance at the British Council Pomology Course, the re-organization of the senior research staff, the largest change-over for many years in the membership of the Governing Body ? All are recorded in the pages that follow.

As the time approaches for us to celebrate our half centenary, it is inevitable that there must be frequent changes, but we hope that those old friends on the Governing Body or the staff who have recently retired will feel that the young growing research institute they have known is still as vigorous as ever and that they are leaving its guidance in good hands.

The Research Report that follows under the same cover bears witness to the fact that the Station's energies are being devoted to the good of research in general and of the fruit-growing industry in particular.

Obituary

The Bradbourne Park Farm Sub-committee (now the Farming Sub-committee) was formed in the dark days of 1941, when the Station took over the farming of the Bradbourne estate and started arable farming on a large scale. On that occasion and for the next sixteen years Mr. W. Alexander was always at meetings, usually having been round the farm without fuss on many intervening occasions. He would never take the ' Chair ', but the help he gave, first to Mr. Amos and later to Mr. Villiers, in our excursions into arable farming and keeping store cattle have been invaluable. The great sense of loss felt by the Sub-committee and by the Governing Body, of which he was a member from 1945, was expressed by Mr. Owen English in July. It is a pleasure, however, to know that the family connexion will be carried on by his son, whom we welcomed on the same occasion.

Three years ago we recorded the retirement of Mr. G. T. Cook after seventeen years' service on the Executive. We were sorry to hear of his death in March. We also regret to report the death of Mr. T. D. Harris, who represented the Kent County Council on the Governing Body for six years.

It was with particular sorrow that we learnt of the untimely death of Mr. C. G. Harker, one time Secretary of the ACE growers, who helped us very much in the early days of the Essex Red Spider Investigations.

As we go to press, we feel we must add our brief contribution to the many appreciations of the late General Sir Ivor Maxse, who died at the age of 95 on 28th January 1958. It seems hardly credible that when he started fruit growing on his retirement from the Army in 1926 he was already a famous soldier, having commanded the XVIIIth Army Corps at the Battle of the Somme in 1917. The writer of his obituary in *The Times* records that he was ' probably the most dynamic trainer of troops for war that the British Army has known in modern times '. It will be for others to say how successfully he applied his abilities as the trainer of men to the art of training fruit trees. Without doubt he was the pioneer in intensive fruit growing and much of the knowledge that we have today emanates from his experience and observation. For our part, when he was appointed to represent the West Sussex County Council in 1935, we were even then ready to greet him as ' a very old friend of the Station ', and when he retired as a Governing Member in 1948, he continued to serve the Station as a Trustee of the Development Fund, taking a close interest in our affairs. We have much to thank him for and shall be the poorer without him.

Governing Members

Last year we reported the resignation of Professor V. H. Blackman as Vice-chairman. It is now our pleasant duty to record his election as an Honorary Fellow of the East Malling Research Station Association and the placing of a portrait, painted by Mr. R. Lewis, in the Director's Office at Bradbourne, alongside Wellington, Hatton and the Chairmen.

The year has seen the triennial re-appointment of the Governing Body and it is sad that the new list lacks many names, some of which have adorned it for many years.

The senior by many years among those who have now retired is Mr. W. Talbot Edmonds, the sole surviving representative of the Kent Farmers' Union on the original Committee of Management. Mr. Edmonds is a very old friend to many of us and it was undoubtedly largely due to his influence

and advocacy that the Station came into being. He was a former Chairman of the Building Sub-committee and during his time many of the now familiar buildings, including Bradbourne House and the Staff Canteen, were acquired and adapted to our needs, or erected. For many years he has presided over the annual meetings of the Plant Prices Sub-committee and anyone who has attended those meetings will appreciate that his task was not always an easy one. But that is but the bare bones, for if ever the Station has needed a friend among fruit growers, Talbot has been among the first to come forward. On behalf of the Governing Members, Sir Edward Hardy presented him with a gold fountain pen (which strangely enough was one of the few implements he seems never previously to have possessed) to show the appreciation of his fellow Governors and, what may possibly have pleased him even more, a little later on at an intimate gathering at Bradbourne, the appropriate memento of an antique snuff box was presented to him by his many friends on the staff. Mr. Edmonds and Mr. Alexander, whom, alas, we have already mentioned, are replaced by Mr. E. Vinson and Mr. R. D. Webb, both of whom we welcome warmly.

Dr. H. V. Taylor's name first appeared as an Honorary Member of the Committee in 1929 and until he retired from the Ministry of Agriculture he had many contacts with the Station and often helped us. In 1948 he succeeded the late Sir Frederick Keeble as the Ministry's official representative. He now makes way for Mr. J. M. S. Potter, Director of the National Fruit Trials, Brogdale, who is no stranger to many of us, and we know he will maintain the prestige established by his predecessors.

Next we must acknowledge our debt to Mr. L. J. Cook, who has represented the Horticultural Trades' Association since 1930. It has meant much to the Station's research programme and our ability to hand on the benefits of its results to growers to have the backing of the fruit tree nurserymen, and we are sure that Mr. A. S. Fromow, already a well-tried friend, will carry on ably the tradition of co-operation established by Mr. Cook.

We can hardly regard our connexion with Professor W. Brown as ending, for he is still Assistant Editor of the *Journal of Horticultural Science* and so maintains a close interest in the Station's work. Although it was not until 1938 that he succeeded the late Dame Helen Gwynne-Vaughan as the representative of London University, many of us have known him for much longer, and more than one member of staff was trained under him at the Imperial College. He is now succeeded by Professor L. J. Audus, who is very welcome.

The retirement of Professor T. Wallace, Director of Long Ashton, is the occasion also for his replacement on the Governing Body by his successor, Professor H. G. H. Kearns, whom we shall look forward to seeing here very often. Wallace was a familiar figure at East Malling in the ' twenties ' and, though he did not join the Governing Body until Professor Barker's retirement in 1943, it is symptomatic of our affectionate respect for him that many names familiar at East Malling were on the list of those who supported the presentation made to him on his retirement from Long Ashton. We must always be grateful for the time that he gave to our affairs among his many other duties. During his time the association between the two Stations has become very close. In October he was elected an Honorary Life Fellow of the Association.

Another of our very old friends and associates among fruit growers is Mr. W. P. Seabrook, who was elected to represent the Members of the Association in 1945. In 1952 we had cause to thank him for his interest in the sports pavilion, and members of the Research Staff will remember a visit to his Essex farm in 1954, when three generations of the Seabrook family were present. But that is a recent occasion, and the first books of the Station record a collection of rootstocks received from ' W. Seabrook & Sons ' in November 1912, while the rootstocks now known as M.XXII and M.XXIII originally came here as Seabrook's A and B.

Mr. A. M. Bear, who has represented the Members since 1951, has also retired. The new members elected by the Association are Mr. P. Wheldon, who was co-opted to the Executive Committee in 1954 and a visit to whose farm in September we record elsewhere, and Mr. C. R. Favell. It is with some satisfaction that we note that among our Governing Members there are now seven former students of Wye College—so the connexion continues.

Last year we lamented the retirement of Mr. M. B. Crane. The John Innes Horticultural Institution have now appointed Dr. K. S. Dodds, the Director, to replace him.

Finally, we must thank Professor G. E. Briggs, who represented Cambridge University for six years, and Sir Ian Heilbron, whose many other commitments did not enable him to continue for a second three-year period. Dr. S. D. Garrett now comes to us from Cambridge, while Mr. J. E. Martineau, who was appointed previously by the Brewing Council, now replaces Sir Ian as the representative of the Research Fund Committee of the Institute of Brewing. In his place we welcome Lt.-Col. F. N. Richardson.

Mr. A. P. Preston was re-elected as Staff Representative on the Governing Body for a further year.

We do not remember ever having to record so many changes in our Governing Body in one year ; we hope that those who will no longer attend our gatherings will realize how much we have valued

their services and we look forward to many happy meetings with those who have succeeded them.

The annual Governing Members' Day, with its special programme of recently initiated research projects, was held on 26th June 1957 ; fourteen attended. In the laboratories, an illustrated talk on nematodes and their possible connexion with tree decline was followed by an introduction to the study of leafhoppers, particularly those concerned with the spread of virus diseases such as Green Petal of strawberries. In the plantations, recently planted apple, pear, plum, and cherry trials were visited, and the design and purpose of each were explained. Work on new loganberry selections was also seen.

Committees

The names of members of the Executive Committee are recorded at the beginning of this Report. New members are Professor Audus, Professor Kearns, Dr. Dodds, Mr. Martineau, Mr. Fromow, and Mr. Vinson. The Finance and Executive Committees met quarterly as usual and, at the June meeting of the latter, Mr. T. Neame and Professor T. A. Bennet-Clark were unanimously re-elected Chairman and Vice-chairman respectively, and Mr. J. W. S. Mount Chairman of the Finance Sub-committee.

The appointment of Professor R. H. Stoughton as Principal of University College, Achimota, Ghana, and his consequent departure for West Africa in the autumn, inevitably entailed his resignation as a co-opted member of the Executive and we shall miss him very much. This event, together with the election of Mr. Wheldon to the Governing Body, left two vacancies. One of these, we are glad to say, has been filled by Professor G. E. Blackman and we were only sorry that his father was unable to be present when we welcomed him in October.

Much of the detailed business of the Station being conducted by its sub-committees, Members will wish to know to whom they are indebted for the good work they do. The following have been elected for the next three-year period in addition to the officers of the Executive and the Director who are members *ex officio*.

Finance : Mr. J. W. S. Mount (Chairman), Professor V. H. Blackman, Sir Edward Hardy, Sir Albert Stern, Mr. S. R. Dixon, Mr. J. F. Towner, Mr. P. Wheldon.

Building : Mr. J. F. Towner (Chairman), Mr. S. R. Dixon, Mr. R. D. Wickham, Lt.-Col. C. L. Newitt, Mr. E. Peter Day, Mr. E. Vinson, the Staff Representative.

Plant Prices : Mr. J. W. S. Mount (Chairman), Mr. G. E. Tuker, Mr. E. Bruce Gibson, Mr. T. H. Rivers, Mr. J. S. Chivers, Mr. A. S. Fromow, Mr. J. Matthews, Mr. S. R. Dixon, Mr. R. E. Hardwick.

Farming : Mr. Owen English (Chairman), Mr. J. Alexander, Mr. S. R. Dixon, Mr. B. S. Furneaux, Mr. D. J. Moor.

Scholarship : Professor T. A. Bennet-Clark (Chairman), Professor V. H. Blackman, Professor G. E. Blackman. Dr. E. E. Cheesman and Mr. T. N. Hoblyn are invited to attend meetings.

Bradbourne Tree-siting : This is an *ad hoc* sub-committee appointed in 1957 to advise on the siting and planting of ornamental trees in the surrounds of Bradbourne. Sir Edward Salisbury's advice has been sought and given ; Miss A. B. Beakbane, Mr. T. N. Hoblyn and the Staff Representative are members.

The following paragraphs record some of the events of the year not mentioned under other headings.

Visit of H.R.H. Prince Philip, Duke of Edinburgh

The highlight of the year was provided by the informal visit on 30th April of H.R.H. Prince Philip, Duke of Edinburgh. Accompanied by Lord Cornwallis, Lord Lieutenant of Kent and a trustee of the Research Station, H.R.H. arrived by car early in the afternoon and was welcomed by the Director and Governing Members at Bradbourne House. He then mounted a farm trailer and spent the afternoon inspecting the experimental farm and visiting the research greenhouses and some of the laboratories. During his tour he was able to meet many members of the Research Staff and talk with them about their work with the minimum of formality. After taking tea in the Pomology laboratory, H.R.H. left the Station by helicopter from the sports ground. The Committee would thank particularly many members of the Research, Administrative, and Farm Staff who, while they had no opportunity to demonstrate their own work, helped so materially to ensure that the arrangements worked smoothly.

Finance and the Research Programme

It is inevitable that in a year in which the whole nation has been called upon to tighten its belt, there should be some repercussions on the Research Station. Nevertheless, the Committee wish to allay at once any fears that any important item on the research programme has been curtailed or postponed in consequence. The rapid expansion of immediate post-war years, both in staff and research buildings, has, of course, been slowed down ; Heads of Sections have had to look critically at

their experimental programmes to ensure that energy is not being expended on unnecessary work, while proposals for new experiments are limited by the available vacant land on the farm. Nevertheless, where developments have been shown to be essential, with the support of the Agricultural Research Council, it has been found possible to allow for them. Thus, a new experimental glasshouse with special temperature and humidity controls for use in the important work on Apple Scab has been provided. Mainly with our own maintenance team, a new meeting room at the laboratories has been erected and will be ready for use in autumn 1957, while repair work and redecoration in Bradbourne House have slowly but steadily gone ahead.

V. H. Blackman Research Studentships

As reported last year, we were in a position to offer a studentship to start in October 1957. Although this was advertised and the rather few applicants interviewed, it is unfortunate that no sufficiently qualified postgraduate was found who was also willing to accept an offer.

The studentships will be advertised again in January 1958, we hope with a better response. At the same time, applications will be invited for the new *Beers' Research Scholarship*, open to postgraduates of London University and of the same value as a Blackman Studentship.

We still hope to attract really first-class young men who, following their training, will be an asset to research in the years to come.

Buildings, maintenance, land, etc.

Apart from the two new buildings mentioned above, the main work of the year has been the maintenance of the existing ones, no light task. We have again to thank Mr. J. F. Towner, Chairman of the Building Sub-committee, on whose seventh annual inspection the year's work was planned. However, we may well record the transformation of the old heating cellar beneath the E.M.B. Building for work by the Biochemistry Section : it is now approached by a covered-way and glazed laboratory. A new telephone switchboard has been installed and it is now possible to make many internal calls automatically. Also, garages have been added to two of the smaller staff houses in Church Fields ; it is planned to build on to the other two houses in the same way in the near future.

Last year we noted the very practical interest of the Pilgrim Trust in the redecoration of the Great Hall at Bradbourne. As we write this is nearing completion ; at the same time other repairs and redecorations in the house are gradually being undertaken as opportunity allows.

A very pleasant event has been the repair of the chairs in the Great Hall at the personal expense of members of the Executive Committee, materially aided by a retiring gift from Mr. Talbot Edmonds. When the Great Hall re-opens, there will be sufficient comfortable chairs to seat the whole Committee. It may be recalled that these chairs together with the table came from Linton Hall, the residence of the late Lord Cornwallis.

Many of the lovely trees at Bradbourne are now at their prime or getting past it. To ensure that future generations do not find Bradbourne denuded of trees, a sub-committee was formed to draw up, with the expert advice of Sir Edward Salisbury, a long-term plan for siting and planting trees to ensure that the character of the Bradbourne estate is preserved. The first trees are to be planted during the winter 1957-58 and we have to thank Mr. A. S. Fromow for his generosity in providing sixteen of those needed.

The Grange and the Staff Canteen both reported satisfactory financial years. The former was full for most of 1957, while the latter finished the calendar year 1956 with a sufficient surplus to enable many necessary replacements to be made in the kitchen. However, at this juncture we must show the red light ; it is getting very difficult with few new arrivals on the staff or long-term postgraduates to keep the Grange full. The same factor is affecting the Staff Canteen—a continual rise in costs, coupled with a slight but real decrease in usage have made it necessary to increase prices in 1958 for the first time in five years.

There have been no additions to the land at the Station. Constant efforts are being made to use the land we have to the best advantage, aided by the Farming Sub-committee and all senior members of the Research Staff, not to mention Mr. Villiers and his assistants. At the same time possibilities of carrying out trials on Experimental Horticulture Stations and growers' plantations are not overlooked, though inevitably work done at a distance must carry with it some loss of that intimate association between the experimenter and his material which is so often essential to success.

Finance

The Research Account and Experimental Farm Account

In the Research Account, staff salaries, national insurance and superannuation have increased by £15,340 on the previous year and total £158,305. This increase is the result of pay revisions and normal annual increments, and has been met in full by the grant from the Agricultural Research

Council. Expenditure on laboratory expenses, etc., and general maintenance increased by £7,097 but almost £6,000 of this was the new liability of the Station for general rates. These expenses were met mainly by the Council and a grant of £1,350 from the East Malling Research Station Association. Farming Members are acutely aware of the increases in farm wages and this item shows an increase of £3,502 on 1955-56 in the Experimental Farm Account. Expenditure on all other heads was within £1 of last year and, as then reported, that was a reduction of £3,000 on 1954-55. Despite improved sales, wages were thus mainly responsible for an increase in the cost of the experimental farm to £27,409, this sum being met by the Council.

The East Malling Research Station Association

The membership of the Association at 1,937 is the same as in the previous year although the distribution between life and annual members has slightly altered. We still think that there are many growers who are unaware of the advantages of membership and who could, with a little persuasion, be induced to swell the total to 2,000 members or more.

The Income and Expenditure Account shows again the valuable contributions made by the Association, not only to research but to the social life of the Station. The grants for the laying of a hard netball court and the surface dressing of the cricket pitch were particularly appreciated by the

The East Malling Research Station Association Income and Expenditure Account

1st October 1956 to 30th September 1957

Expenditure	£ s. d.	Income	£ s. d.
Research Grant	1,350 0 0	Subscriptions and Donations	4,141 15 6
Evening Class Fees	8 7 6	Miscellaneous Receipts	18 0
Staff Amenities	175 0 0	Interest on Investments	135 4 8
Netball and Cricket Pitches	174 1 8	Interest on Loan	8 0 6
Scholarship Fund	600 0 0	Refund of Income Tax	375 13 4
Portrait	168 18 0		
Farm Pensions	250 0 0		
Annual Report Index	154 0 7		
General Expenses	1,543 4 6		
Surplus	237 19 9		
	£4,661 12 0		£4,661 12 0

Property Account

	£ s. d.		£ s. d.
Repairs, Rates, Insurance, etc	279 13 6	Rents	204 8 5
		Deficit	75 5 1
	£279 13 6		£279 13 6

The East Malling Research Station Association Balance Sheet

at 30th September 1957

	£ s. d.		£ s. d.
Accumulated Members' Fund :		Freehold Property at Cost :	
Balance at 30th September 1956	16,053 19 0	'Fircroft', 'Grange', and 31 Buckland Lane, Maidstone	11,359 14 9
Add Surplus for Year as per Income and Expenditure Account	237 19 9	Investments at Cost—General Fund (Valuation 30th September 1957, £3,162)	4,500 0 0
	16,291 18 9	Scholarship Endowment Fund :	
Scholarship Endowment Fund	6,911 6 9	Investments at Cost 6,263 3 0 (Valuation 30th September 1957, £5,819)	
Provision for Farm Pensioners	521 9 10	Cash at Bank 648 3 9	
Sundry Creditors	1,130 4 6		6,911 6 9
		Loan Account	120 0 0
		Accumulated Deficit on Property Account	76 16 4
		Sundry Debtors	24 9 3
		Cash at Bank	1,862 12 9
	£24,854 19 10		£24,854 19 10

two clubs concerned, while we must certainly draw attention to the contribution of £600 to the Scholarship Fund.

The Balance Sheet shows a General Fund investment of £1,500 during the year. The Scholarship Endowment Fund stands at £6,911 which is not quite sufficient for four years if the envisaged three scholarships are awarded. There is now a reserve of £521 towards the pensions of the nine farm men that will eventually be paid by the Association. Cash at bank is more than sufficient to cover sundry creditors.

Members' Days

Four Members' Days were held during the year with a total attendance of about 600.

Preceding the Amos Memorial Lecture in November 1956, the Physiology Section showed some of the work on growth studies, which is aimed at an understanding of rootstock influence on tree vigour, and the effects of certain pruning and dis-budding treatments on the production of laterals.

The fruit storage experiments are being continued, and once again the Association was invited to see some of the results. A part of each sample was kept in cold store, and the other part in gas store with scrubbers. The latter was on view on 27th February, with exhibits showing the effects of grassing down on fruit colour and the types of rots and breakdowns found in the samples. Results were discussed and mention was made of the search for fungicides to control storage rots.

After the Annual General Meeting on 14th May, informal farm walks were organized, each of which provided an opportunity of seeing the work on a particular research project, e.g., rootstocks, soil management, scab, virus diseases, strawberries, etc.

On 20th July the programme was arranged for the benefit of amateurs, and included demonstrations and talks at Bradbourne on tree forms suitable for the private garden, and on pest and disease control on a garden scale.

Amos Memorial Lecture

The ninth lecture was delivered at the Research Station on 15th November 1956 by Professor F. G. Gregory of the Research Institute of Plant Physiology, Imperial College of Science, whom we would take this opportunity of congratulating on the award recently of the Royal Medal of the Royal Society for his distinguished studies in plant physiology. Members who were unable to attend were able to read his stimulating paper in full in the 1956 Report.

Staff

During the year a gradual re-organization of the senior staff has commenced and, although it is not likely to have its full effect for a year or so, some changes have already taken place. In future Mr. T. N. Hoblyn and Dr. R. V. Harris will act jointly as Advisers to the Director, while Dr. H. B. S. Montgomery is now Assistant to the Director. As from the 1st October 1957, after thirty years, Mr. Hoblyn handed over the duties of Head of the Statistics Section to Dr. S. C. Pearce, who has acted as his deputy in that Section since April 1948. Earlier in the year, Dr. A. F. Posnette and Dr. J. E. Crosse were appointed as Deputy Heads of the Plant Pathology Section for virus and mycological studies respectively, and Dr. G. H. L. Dicker was invited to assist Dr. A. M. Massee as Deputy Head of the Entomology Section.

Again we have to record the retirement of members of staff who have served the Station for very many years, while yet another who was not on the staff but who has lived and worked with us for so long that we have almost come to think of him as one of ourselves, has relinquished his post to a younger man.

Mr. A. C. Painter first came to the Station as a volunteer in June 1925 and after serving an apprenticeship, like so many others of his time, as a recorder, took charge of the marketing of our fruit from 1927 until he was re-called to the Navy in 1939. Returning in January 1946, he joined the Scientific Liaison Section and was from then on a familiar and untiring figure to many visitors, while his meticulous editing of our Annual Reports will long be a model to those who succeed him. Like Mr. Grubb and Dr. Vyvyan, retirement does not mean complete severance and we hope to see him among us for many years to come.

In the same year that Painter took over the duties of 'Assessor of Market Qualities' (1927) Mr. P. R. Wood joined the staff, under the late Miss M. K. Glover, as Book-keeper. While his name may not be as well-known to Members, the Research Staff have cause to be grateful to him for his care of their finances, to say nothing of those of the Station as a whole, over a long period.

Lastly, Mr. W. G. Kent, Fruit Advisory Officer for the South-eastern Region, retired in May after twenty-seven years' residence at the Station, first as Advisory Officer to the Kent County Council and later as a senior specialist in the N.A.A.S. Throughout that period he has been closely associated

with the Station, attending meetings of staff and social activities, and being regularly available for consultation. Our good wishes go with him in his retirement. We welcome the return of Mr. F. A. Roach to Kent as his successor.

Early in the year the importance of the Station's contributions to horticultural science was again recognized by the award of the Order of the British Empire by H.M. The Queen in the New Year's Honours to Mr. T. N. Hoblyn, who has given many years of valued service to the Station and to the fruit-growing industry.

In the Pomology Section, Mr. R. I. C. Holloway came to assist Miss Glenn on the recording staff in October 1956, replacing Miss M. G. Fromow who had taken over the strawberry work from Miss Wilson, as reported last year. Miss G. A. Blair resigned her post on her marriage, in September, to Mr. M. M. MacNeill, who is in charge of our greenhouses, and we offer our good wishes to them both. She is succeeded by Mr. M. V. Labern.

In the Statistics Section, Mr. J. A. Thompson joined the staff in February. Mr. D. A. Holland went to Aberdeen University in September to undertake a year's study in the A.R.C. Unit of Statistics ; we shall look forward to his return next year.

Mr. C. A. Priestley joined the Plant Physiology Section in November 1956 to study the seasonal variation in carbohydrates in fruit trees and their relationship to growth and cropping.

Dr. A. E. Flood's departure for the United States and Canada in September is mentioned elsewhere. Mr. A. R. N. Gorrod came from the Hannah Dairy Research Institute in Ayrshire to join the Biochemistry Section in July.

The Pathology Records Group lost Miss P. Webb in March, on her departure for Kenya, and Miss S. E. Ball, in April, who resigned to be married. They have been replaced by Miss H. P. Insley and Miss E. J. Basker. Miss C. M. E. Garrett was appointed to the Plant Pathology Section in August to a new post to assist in research on bacterial and fungal diseases.

The work of Mr. L. A. Lickerish, who was formerly attached to the Plant Protective Chemistry Section, now forms part of the Entomology Section's programme.

Changes among the Assistants (Scientific) have not been so numerous as in some years past ; we regret we have only space, however, to mention one or two of them. Mrs. O. B. Wenbourne resigned in February after five years' recording in the Pomology Section, and Mr. J. F. Thompson left the Entomology Section in September to join the N.A.A.S. Miss V. Wood (Biochemistry) resigned on her marriage to Dr. D. S. Kirkham, of the Plant Pathology Section, in September. Miss J. A. Dolding is now senior computor in the Statistics Section.

We are fortunate in having no changes to record in the senior members of the Farm Staff for the third year in succession, while the list of those with more than twenty-five years' service remains the same as last year. Such continuity on the farm is of great value not only to Mr. Villiers but also to the Research Staff who rely very greatly on the farm for the culture of their field experiments. We note with pleasure that Miss Kathleen Greenstreet is now in charge of the Bradbourne Gardens.

In the ' Office ' we would congratulate Miss J. M. Coy, who first joined the staff in 1931, on her marriage in September. Mrs. Coney, as we must now learn to call her, will be remaining at the Station on a part-time basis until the end of 1957.

It is nearly twenty years since we first recorded the Station's indebtedness to members of staff for the smooth running of such institutions as the library, the greenhouses, the photographic studio and canteen. Since then both the number of committees and the work entailed have grown, even though appointments, e.g. librarian, greenhouse superintendent, photographer, housekeeper, have been made that take some of the weight off these voluntary officers. Nevertheless, their work is still necessary and greatly appreciated.

Organized Visits

During the past few years we have visited the major research stations accessible in a day's journey from East Malling and it was very appropriate that we should select the rapidly developing Experimental Horticulture Station at Efford, Hampshire, for one of our organized visits this year. On 5th July the party, about forty members of staff, was welcomed on arrival by the Station Director, Mr. P. H. Brown, who also spent the day with the visitors and supplemented the information given by his staff concerning the many experiments in progress. The visit, which was superbly organized, was not confined to the tree and soft fruit sections but included also the vegetable, the glasshouse and protected cropping sections. The picture of the Station as a whole obtained in this way should be especially valuable to members of staff who may wish to propose experiments to be run at Efford.

On 3rd September a very useful visit was paid to the farm of Mr. Peter Wheldon at Newton, in Suffolk. Great interest was taken in his methods of growing dessert apples, and lively discussions developed on such subjects as irrigation, manuring and the merits of swards. Plantations of other fruit seen included pears, cherries and black currants.

The last visit of the season was made in the afternoon of 18th September to Mr. Gordon Smith's farm at Loddington. A very wide range of crops was seen, in fact almost all the commonly grown fruits were represented with the addition of cobnuts and mushrooms. The fact that Bramley's Seedling trees planted in 1890, probably the first commercial planting of this variety, and the 'mothers' of our own trees in the rootstock trial, were still flourishing and bearing large fruits testified to the high standard of management on the farm. A feature of this farm was the range of soils encountered in going down the escarpment and the effect of these soils on the crops grown.

We are very grateful to Mr. Brown, Mr. Wheldon and Mr. Smith for the warm and hospitable reception they gave us and for all they did to make these visits so valuable.

Social and Athletic Activities

Miss M. G. Fromow succeeded Mr. Rutter as Social Secretary and continued in office until September 1957. During the year, which she reports was an active and enjoyable rather than a highly successful competitive one for the sports clubs, the Netball Club was placed fourth in the newly formed Maidstone League. Both Hockey and Cricket Clubs held their annual matches against the Members ; the hockey match ended in a draw, but the Members won the cricket match by a small margin after one of the most exciting matches for many years. The Table Tennis, Tennis and Squash Clubs all organized ladders and tournaments, some members of the last entering for a tournament organized by the Maidstone Squash Club. A hard netball court at Bradbourne, provided by the Association, should facilitate all-the-year-round play for our young ladies. We again entered a team for the Kew-Wisley cross country race. The Boat Club seem to have enjoyed the hot weather at the beginning of the summer ; we regret that we had forgotten that there was any. On the other hand, parents will not forget the first wet Children's Party in July, though we are assured that our young guests thoroughly enjoyed themselves. In the autumn a special evening was arranged entirely for the Farm Staff. The harvest supper which was the main event describes itself but hardly covers the hilarious informal entertainment that followed, which threatened at times to become out of hand. The Christmas party entertainment, produced by Miss Seymour for the tenth time, again took the form of a pantomime—the title 'Boobs in the Wood' gives little idea of what it was all about. Each year Miss Seymour declares that it is her last—nevertheless, after the Great Hall re-opens in February 1958, we look forward to reporting that she has 'done it again'. Despite the complaints of the dramatic critics in the national press against such activities, both the Play Reading and Music Clubs have organized coach parties to plays and concerts in London, which we must confess have proved very successful and are likely to be repeated. In our attempts at brevity, we find we have omitted to mention the evergreen Garden Club which held a successful Produce Show in September.

Postgraduate Students

As already reported, no award of a Blackman Research Studentship was possible in 1957. Indeed, there are still no postgraduates, other than members of staff, registered for higher degrees with London University. Most applications are for periods of study of up to one year, the financial implications of a three-year stay being apparently too much for most.

Mr. A. C. Mason was awarded the M.Sc. degree for a thesis submitted in March entitled 'The determination of elements in plant material'. Miss M. P. Denne was awarded the degree of Ph.D. in March by the University for work completed before coming to East Malling.

Last year we reported the arrival of three Colonial Office students for periods of about a year's training in various Sections. Mr. R. A. Whitehead, who specialized in plant breeding during the latter part of his stay, left in September for a year's further training in Trinidad, whence he will take up an appointment at the West African Institute for Oil Palm Research in Nigeria. Mr. R. W. Smith and Mr. J. F. Longworth sailed for Ghana in November 1957 to join the staff of the West African Cocoa Research Institute. Before they left another Colonial Office student, Mr. D. J. Butt, arrived for nine months' study in the Plant Pathology Section.

Dr. S. M. Singh completed his year in the Pomology Section in December 1956, while Mr. A. Gur returned to Israel in August 1957 after ten months.

All our other visiting students and research workers worked for varying periods in the Plant Pathology Section. A British Council grant enabled Dr. Z. Borecki of Skierniewice, Poland, to work on storage diseases of apple for ten months from April. Dr. M. K. Hingorani of New Delhi assisted in research on Bacterial Canker of *Prunus* for four months from February, and in August Dr. A. Mezzetti of Bologna, Italy, came for six months to study storage diseases of fruits. Staying only for short periods, Mr. A. I. Eloja of the Philippines came for the month of June to study virus diseases, while Mr. L. M. Wassenaar of Wageningen, Holland, spent a week here in April to gain experience of our strawberry grafting methods. Dr. Evenhuis, also from Wageningen, visited us for a week in May.

Temporary Recorders

We must again thank supervisors of studies at the Universities for recommending to us students, most of whom helped very considerably during the summer with field recording. Excellent reports have been received of nearly all of the seventeen accepted, one for the second year running. Exeter University provided four students and three came from Wye College, while King's College, London, and Reading University provided two each. Others were from Newcastle, Leeds, Bristol and Southampton.

We are still receiving fewer applications than we should like and hope that some of the Universities and Colleges from which we have had excellent young people in the past, will have more potential research workers to send us in 1958.

Plantation Assistants

Receiving many more applications than there were vacancies, the selected team of ten was a very useful one in 1957, so much so that it was not easy to decide to whom the Worshipful Company of Fruiterers' medal and prize should be awarded. The winner, Mr. R. E. Obbard, is now working for Mr. R. D. Wickham at Brenchley. We congratulate Mr. J. F. Thompson, the winner two years ago, on passing his N.D.H. in fruit growing.

Research Staff have cause to be grateful for the assistance given by plantation assistants in carrying out the many, often specialized, operations on their field experiments under the supervision of the Farm Staff ; in return, the lectures, expeditions, etc., organized for them, as well as the experience they gain, must be invaluable to those who are at the start of their horticultural careers. We know that it is appreciated.

Staff Discussions

Arrangements for staff discussions are now in the hands of several Heads of Sections as well as the Staff Representative. Four discussions of interest to all were held at Bradbourne and attended by most of the scientific staff. In addition, four inter-sectional meetings were arranged ; these were designed to enable two or more Sections to discuss in detail common problems and aspects of their work. Several lively debates, we can almost call them, on experimental methods were very well attended and testified to the intense interest of the scientific staff in technical aspects of their researches.

Research Tours

In September, Dr. A. E. Flood, Head of the Biochemistry Section, with the aid of a fellowship from the Kellogg Foundation, left to work for six months at the California Institute of Technology, Pasadena, after which, through the good offices of the Agricultural Research Council, he plans to spend three months in Canada.

Three members of staff were enabled to attend the International Congress of Crop Protection in Hamburg. Dr. A. H. M. Kirby and Dr. M. H. Moore combined attendance at the Congress with visits to research centres in East and West Germany and in Belgium. Dr. R. S. Pitcher also attended the symposium on nematology at Hamburg.

Dr. A. F. Posnette left in September for the U.S.A. for a month's visit at the invitation of the University of Missouri, to see the work in progress on virus diseases of fruit trees and on the production of virus-free material. He also advised the University Department of Horticulture on their research programme with special reference to virus diseases of pome fruits.

Mr. R. Cropley visited Skierniewice, Poland, during a vacation to discuss virus diseases of fruits as a guest of the Research Institute of Poland. This re-opening of contacts there is very welcome.

It must be obvious to those who read these Reports that isolationism is not practised at East Malling. As usual we have been advised of numerous visits to other research institutes, experimental horticulture stations and fruit growing areas. As these are now an integral part of our research programme there is no need to give details.

Collaboration and Outside Trials

Those who have followed the story of the Station in these Reports can have little doubt of the expansion of our contacts, not only in Great Britain but all over the world, that has taken place in the last ten years.

This year we would draw special attention to our contacts abroad. A year ago we recorded the successful virus symposium held here, and the visits of Dr. Posnette to the United States and of Mr. Cropley to Poland are further symptoms of the world wide interest in virus research at East Malling,

while a glance at other sections of this Report, viz. visitors, postgraduate students, will reveal other evidence. Again, the visit of three Yugoslavs to learn about cotton breeding from Dr. R. L. Knight, while hardly part of our work, further illustrates the contacts with other countries.

But perhaps the most surprising event of the year was the response to invitations to the Pomology Course, arranged by the British Council in March. Like its predecessor, in 1950, the course was designed for those starting their careers in horticultural research ; but looking down the list of those from ten European countries who came, we find the names of two directors, particularly the veteran Dr. Gallay from Switzerland, heads of departments and assistant professors, with several of whom we have been in contact for many years. Altogether, a notable week from which we must have derived as much benefit as our visitors.

It would be tedious to repeat details of the numerous collaborative enterprises with other research institutes and the N.A.A.S., also experiments on growers' farms, some of which have been in progress for many years and are now part of our lives.

One or two new developments should be mentioned, however. An irrigation trial at Luddington on trees already under observation by Long Ashton for another purpose is to be started in 1958, while our Fruit Nutrition Section is very interested in other manurial and cultural studies at Luddington and Efford emanating primarily from our sister research station. Weed control in strawberries and black currants, of joint interest to the A.R.C. Unit of Experimental Agronomy at Oxford and ourselves, is the subject of experiments which should be of great practical value to growers. Both the Pomology and Physiology Sections have an interest in a trial in Sussex for the control of biennial bearing by defoliation. Apple trees staked, at least in their early years, are a part of normal English practice, though always surprising to our North American friends. If we use the right rootstock and prune accordingly, can we also do without stakes ? A trial bearing on this subject has been planted in Sussex.

Widespread spraying trials and studies of insects and diseases outside the Station testify to the growers' intense pre-occupation with the enemies of the fruit tree that he can see, and whose depredations affect the value of his product. We would not belittle for one moment the importance of these studies, indeed, many members of the Pathology, Entomology and Plant Protective Chemistry Sections are in close touch with a wide range of them. Space to enlarge on them is lacking and we can only, as usual, conclude this section by thanking the many who make such work possible.

Scientific Societies and Conferences

At the 4th International Congress on Crop Protection at Hamburg in September, Dr. Kirby contributed papers on phytotoxicity by organomercurials and on the contrasting influence of certain fungicides on orchard fauna in south-east England, and Dr. Moore on the control of Bacterial Canker on cherries. Dr. Pitcher attended the 4th International Symposium on Nematology at Hamburg before the Congress and read a paper on etiological techniques for use with root migratory nematodes.

Dr. Modlibowska attended the 87th International Congress of the Pomological Society of France, at Namur, by invitation, and delivered a paper on spring frost problems. Dr. Rogers attended the third British Weed Control Congress.

Dr. Posnette visited Wageningen, Holland, for the International Potato Virus Conference. Mr. Hoblyn and Dr. Posnette were present at the Cocoa Conference in London, where the latter read a paper on the pollination of cocoa flowers.

The meetings of the Society of Experimental Biology have provided opportunities for presenting and discussing various aspects of the research on growth. In January, Mr. Barlow staged a demonstration on the effects of defoliation on shoot growth, Dr. Vyvyan gave a paper on ' An analysis of growth and of the leaf-weight ratio in some one-and two-year-old apple trees ', and Mr. Maggs gave a paper on ' The growth of root and shoot under conditions of extreme vigour '. In April, Dr. Vyvyan and Mr. Maggs presented papers on ' Factors influencing the number, length and diameter of lateral shoots in young apple trees ', and ' The relation between apparent net assimilation rate and total increase in weight in young trees ', respectively.

At a conference of the Society of Chemical Industry, Pesticides Group, in London in December, Dr. Moore contributed a paper on ' Concentrate spraying '. Dr. Crosse read a joint paper with Dr. Pitcher to the Linnean Society in March on ' A disease complex of strawberry involving a nematode and a bacterium '.

At a meeting of the Association of Applied Biologists in December, Mr. Llewelyn read a paper on ' The scorching of apple leaves by copper sulphate '. At the British Association in Dublin, in September, Mr. Barlow took part in the session on plant growth substances with a paper on ' Hormones and fruit tree growth '. Many other meetings of scientific societies, and conferences of research workers and advisers, have also been attended.

Information Services

Correspondence, exhibits, lectures and demonstrations

About 1,400 letters and many telephone calls about subjects which we are investigating were received and mainly answered by the Scientific Liaison Section, so that less than one-third were replied to direct by the specialists concerned. Many of the seventy-one visits to fruit farms were closely linked with the acquisition of information vital to the progress of developing lines of research.

At Chelsea we demonstrated the role of plant anatomy in research on tree fruits, and at the Kent Cherry and Soft Fruit Show in July the Green Petal disease of strawberries. Once again we assisted the Institute of Brewing with material for the hops section of the Barley Mow exhibit at the Three Counties Show, at Gloucester and the Royal Show at Norwich. Research on the nature of wilt-tolerance in the hop was also displayed at the exhibition of new varieties of hops in London in November.

At the Linnean Society of London, on the occasion of the President's reception, we showed various forms of frost injury to fruit in different stages of development. Assistance was given to the N.A.A.S. with plants for a strawberry exhibit at the Royal Show, and to the N.F.U. with fruit for the English Apple Exhibition at Leeds, and for the Southport Show. Specimen fruits were also sent to the Otford Horticultural Society's Show.

Thirty-one lectures were given to growers, students and advisory officers, in Berkshire, Cheshire, Devon, Suffolk, Sussex, and in Cardiff, as well as in many parts of Kent. While most of these dealt with pest and disease control (including virus diseases), pruning, irrigation, and propagation also appeared popular subjects. Pruning demonstrations were given in Cambridgeshire, Devon, and Suffolk. One member of staff took part in a ' Brains Trust ' at the R.H.S., London.

The staff assisted with judging at all the major fruit shows, including Marden, East Kent, Wisbech, Maidstone Fat Stock, and the Cherry and Soft Fruit Shows.

Visitors

In all, we had about 1,900 visitors to the Station, of whom more than 500 came from overseas. We were specially pleased to welcome Dr. T. Swarbrick, Director of the Scottish Horticultural Research Institute, Mr. F. P. Knight, Director, and Mr. F. Hanger, Curator, of the Royal Horticultural Society's Gardens at Wisley, Mr. R. A. E. Galley, Officer in Charge of Colonial Insecticides Research, Dr. E. C. Childs, Director of the A.R.C. Unit of Soil Physics, Cambridge, and Mr. J. W. Kennard, Clerk to the Governors of Wye College.

From overseas, amongst many others, we welcomed from Australia Mr. J. W. Bulcock, Agricultural Counsellor to the High Commissioner in London and Dr. D. Martin, Officer in Charge of the Tasmanian Regional Laboratory, Hobart ; from the Belgian Congo, M. R. Pichel, Assistant Director of the Research Institute at Yangambi ; from Canada, Dr. H. Martin, Director of the Science Service Laboratory, London, Ontario, Dr. H. R. McLarty, Senior Plant Pathologist at Summerland, British Columbia, and Mr. E. R. Chudleigh of Ontario ; from Israel, Dr. C. Reznick, Chief of the Plant Protection Service, Tel-Aviv ; from Jamaica, Mr. W. M. Sievright, Minister of Agriculture ; from Japan, Professor C. Yoshii of Kyushu University ; from New Zealand, Mr. A. Osborne, Manager of the New Zealand Fruit Growers' Association ; from Portugal, Professor B. d'Oliviera, of the National Agronomic Research Station, Oeiras ; from South Africa, Mr. D. G. Malan, General Manager of the Deciduous Fruit Board ; from Tunisia, M. J. Touzeau, Chief of the Crop Protection Service ; from Turkey, Resa Bey, Head of the Technical Information Service ; from the United States, our old friend Professor H. B. Tukey of Michigan State University ; and from Nigeria, Mr. C. W. S. Hartley, Director of the West African Institute for Oil Palm Research.

As usual there were many parties. We mention particularly our guests at the British Council Pomology Course elsewhere. Others included members of the N.A.A.S. Analysts Conference and the Advisory Entomologists, the Council of the Systematics Association, members of the Cambridgeshire N.F.U., and a party of trainees from the Midland Bank Training College for Bank Managers accompanied by the Superintendent ; parties of German and of Belgian farmers, fruit and hop growers, members of the National Horticultural Society of France, several parties of Yugoslavs, including one of staff of experimental stations ; a group of Irish advisory officers also visited us. Student parties came from Universities and farm institutes in the United Kingdom, from Germany, including one from the Plant Pathology Institute at Bonn University, and from Alnårp, Sweden. The Bonn party came with Professor H. Braun, while the first of our own postgraduates, now Professor Gunnar Callmar, was in charge of those from Alnårp.

Horticultural advisory staffs were given the opportunity to keep in touch at the annual two-day visit and at the specially arranged rehearsals of Members' Days. The usual refresher courses on rootstock identification and Nettlehead disease of hops were held for the Ministry's inspectors.

Distribution of Experimental Material

Some description of the 1956-57 distribution of surplus experimental material and of the season in 1957 is given in the Farm Report and need not be repeated here.

On the occasion of the Duke of Edinburgh's visit, an exhibit was staged illustrating East Malling's contribution in the form of plant material to research in the Commonwealth. The diversity of the requests we receive is shown by the eighty consignments sent overseas which ranged from one of four thousand rootstocks to British Columbia to a dozen virus-free strawberry runners sent by air to Australia.

The Distribution List issued to Members in August 1957 included further supplies of the Malling-Merton apple rootstocks, the demand for which continues, but only one of the established rootstock varieties, Mazzard F12/1, as it was expected that most of our small production would be needed for research. It was, however, possible for the first time to offer a virus-tested clone of the semi-dwarfing plum rootstock St. Julien A, selected at East Malling many years ago, but only previously issued for research purposes. This rootstock is also of value for peaches.

The list of varieties available as Mother trees is now so long that we cannot undertake to work trees of all varieties each year. However, we will always try to work particular varieties if given due notice. This season we have offered twelve varieties of apple, including the new virus-tested John Innes variety Merton Beauty, thirteen cherries (two for the first time), and the first three pears to survive virus-testing. Other items in the list were much as usual.

During 1956-57 as an interim measure, two hop seedlings D1 and D3, which had given adequate results in cultural trials, are tolerant to Progressive Verticillium Wilt and are of better brewing quality than OR55, were distributed to specialist propagators, on the understanding that the limitations as well as the advantages of the varieties should be made clear to those concerned. These have been eagerly taken up. During the year the wilt-tolerant Wye Bramling Cross OT48 and wilt-tolerant males B7 and B9 have been multiplied with a view to distribution in 1957-58. Finally, the seedling J2, derived by open pollination from Golding 1147 at East Malling, will also be released during the winter 1957-58 on the same conditions as the seedlings D1 and D3.

Station's Publications

Sixty-five scientific papers and sixteen practical articles for growers were published during the year. They are all listed in Part II of the Research Report. Also, the Abstracts and Index to the Annual Reports 1913-1953 was published and a subject index of papers from East Malling in journals, other than the Annual Reports between 1913 and 1953.

Journal of Horticultural Science

Quarterly publication was again maintained, Volume 32 containing twenty-five papers, rather less than Volume 31 because of the need for economy pending a rise in the subscription rate in 1958. Despite this, one hundred new subscribers from all over the world were enrolled during 1957, so that it is now necessary to print additional copies, while again the year was completed without financial loss.

The end of 1957 has brought with it the retirement of Professor Wallace as Joint Editor, a serious loss which all concerned with the Journal must feel. Temporarily, editorial work will be carried on from East Malling in co-operation with Professor Kearns, with the valuable assistance of Professor Brown, pending the appointment of a new Joint Editor from Long Ashton.

Library

For years now we have been acknowledging the great assistance given to the Station by the Chairman of the Library Committee and with this acknowledgement, supplemented by a factual report from the librarian on the use to which the library facilities are put, Members have had to be content. We should now remind them that the Chairman has for many years been the Director of the Commonwealth Bureau and that we have now built up between the Bureau and the Station a very large horticultural library, which includes much specialist literature of value to the Research Staff. The maintenance of the ever growing library, additions to which include the current numbers of nearly a thousand journals and annual reports each year, to say nothing of books, reprints and the annual commitments for binding, is a real problem. Eight years ago, the journals, which are the breath of life to the library, cost us, with binding, about £300 ; today the cost has more than doubled. It is not surprising, therefore, that the Committee, which is representative of all Sections, has tried to nd means of reducing this cost by eliminating redundant annual publications. The result has been

very small, for almost every journal that we take is of value to at least one and very often several members of staff.

Compared with this, expenditure on books is surprisingly small ; nevertheless, during 1957, 122 were added to the library shelves and for many of these we have to thank the Bureau. With their help and the voluntary contributions of Sections, the library has not suffered from financial stringency so far. We trust this state of affairs will long continue, for a living library is essential to efficient research.

RESEARCH REPORT

Part I

THE EXPERIMENTAL FARM

By F. H. VILLIERS, with contributions by M. M. MACNEILL and H. R. BYFORD

From the fruitgrower's point of view the weather in 1957 had little to recommend it, certainly not at East Malling. After a very mild winter, without sufficient frost to benefit the soil, a sharp spring frost on the night of 5th-6th May, when the temperature fell to 28° F., severely damaged most fruit plants. This, in an ' off ' year for plums and several apple varieties, resulted in much reduced crops.

The very hot June and early July suited cherries, and such strawberries as survived the frost were free from *Botrytis*, but as the season progressed the effect of frost damage on fruit quality became more apparent, few apples being unblemished. East Malling was, however, fortunate in escaping the serious hail and gale damage which for the second year in succession affected some parts of Kent, and the abundant rainfall in the late summer gave good fruit size.

The mild early spring weather brought all blossoming dates forward, and Myrobolan plums were in bloom on 4th February, the earliest ever recorded here. Other varieties of plums, apples and cherries also bloomed a fortnight earlier than in recent years, and the first strawberries were marketed on 14th June, 3 days earlier than in 1956, although many of the first blossoms had been killed by frost. The season continued early throughout and apple picking was finished by mid-October, which was, perhaps, the best feature of the season.

Experimental orchards

Top fruits

Apples.—The crop was the smallest since 1944, in which year there was a very severe frost, only 195 tons being harvested as compared with 255 tons in 1956. All varieties suffered some frost damage but Worcester Pearmain and Ellison's Orange less than some others. The crop of Worcester Pearmain (60 tons) was 17 tons more than the light crop of the previous year, but not as heavy as had been anticipated. Although in an ' off ' year, Ellison's Orange yielded well over half last year's record crop. Laxton's Superb was also ' off ' and gave only half a crop. Cox's Orange Pippin did not suffer as much as was at first thought, and except for the low parts of the farm, yields were satisfactory, particularly on the taller trees ; but a rather exposed plantation of trees on M.IX bore scarcely any fruit. Laxton's Fortune, Jonathan, and Egremont Russet all suffered severely and crops were much reduced.

Our two main culinary varieties, Lane's Prince Albert and Bramley's Seedling also carried only half crops, though good sized fruits partly made up for lack of numbers. The Howgate Wonder pollinators in our plantation of Lane's seemed unaffected by frost, some of them, frameworked on Grenadier four years ago, giving 8 bushels of large, good quality fruits per tree.

Pears.—The total crop, 5½ tons from 3 acres, was also disappointing and although the yield of Conference was better than might have been expected, many of the fruits were seedless and misshapen. The crop of Williams' was light and, in Bradbourne Gardens, the lowest part of the farm, there was an almost complete ' wipe out '.

Cherries.—The total quantity, 6½ tons, was almost the same as in 1956, but the quality was very much better as there was little fruit cracking. Early Rivers suffered from poor weather at blossom time and from the subsequent frost, the crop being below average and carried mostly on the higher branches. Bigarreau de Schrecken blossomed profusely in ideal weather and the crop was the heaviest for some years. Our other main variety, Turkey Heart, averaged only 14 lb. per tree.

Some varieties in the young cherry trial planted in 1953, which includes many virus infected trees, carried sufficient fruit to be worth picking for the first time, but the most was only 7 lb. per tree.

Plums.—The combination of an ' off ' year for many varieties with inclement weather proved disastrous for our plum crop and only 7 tons were marketed as against 39½ tons the previous year.

The bulk of the fruit came from the three varieties Victoria, Warwickshire Drooper, and Ontario, with a very useful contribution from our Myrobalan windbreaks. Except for Comte d'Althann's which averaged 100 lb. per tree, gage varieties were hardly worth picking.

Soft fruits

Just over 3 tons of strawberries were marketed from 1¼ acres of cropping plants, considerably more than was at one time expected. The fruit was small through the dry weather, and the loss of early blooms, but the absence of fungal attacks more than compensated for the frost damage.

Three acres of raspberries planted in the autumn of 1955 bore a first small crop of just under half a ton per acre and made good cane growth. Some difficulty was experienced in picking Malling Exploit which seems to adhere tightly to the plug, but whether this was a result of the dry weather or is a characteristic of this variety it is hard to say.

Just under 1 ton of fruit was picked from the small area of cropping black currants in pathology trials. The bushes in the 2 acre block planted last year grew well in spite of the dry spring.

Fruit marketing

For the second year in succession very few Fancy grade apples were marketed. The russeting, cracking and ' frost rings ' spoiled almost as much of the fruit as did the hail storm in 1956. Fruit size and colour were, on the whole, good, and pest and disease control satisfactory, but even so it was a most disappointing season for the packhouse staff. As many as possible of the apples were wrapped and packed in B.S.A. boxes and marketed as ' Choice ', but many did not reach this standard and were simply sized and sold as a ' jumble pack ' in salesman's empties.

Some 1,500 bushels of Worcester Pearmain were put into one of our larger gas stores for six weeks, to spread the season, and the other large store was filled with Bramley's, Lane's, and Howgate Wonder for keeping until the New Year. Of the smaller stores available, one was partly filled with Cox's and the other filled with Laxton's Superb and Barnack Beauty. There did not appear to be sufficient fruit in the Cox store to enable the correct atmosphere to be maintained for long storage and the apples had to be marketed at Christmas. In the store containing the Laxton's and Barnack Beauty the atmosphere has been adjusted to contain 7 per cent of CO_2 and 5 per cent of O_2, and this should enable the fruit to remain in satisfactory condition well into February.

Cherries and plums were again hand sorted and marketed in 8 lb. and 12 lb. chips. Improved prices helped to compensate to some extent for the lack of quantity. The bulk of the soft fruit was as usual sold for processing.

Fresh plantings and grubbing

Several small areas were planted in the autumn of 1957 of which the more important were 1 acre of Williams' Bon Chrétien, Beurré Hardy, Conference, and Doyenné du Comice pears on quince on Deadman field (D1) for studies of the effect of virus on cropping; 1 acre of Laxton's Fortune and Superb apples on a dwarfing rootstock in Egham field (E29) for studies in the control of biennial bearing ; ¾ acre adjacent of Cox's from various sources on M.IX and 1½ acres of apples, pears, and soft fruit on Park Farm (P12) for the use of the Plant Protective Chemistry Section.

In addition two small plots of cherries and plums have been planted on Great East field (G8 and G16) for work on Bacterial Canker and Silver Leaf.

Two rootstock trials were concluded and the trees grubbed in 1957 ; these were the gage plum rootstock trial on Deadman field (D2), and the adjacent free pear rootstock trial (D4). Other areas cleared include a further 1¼ acre of Worcester Pearmain on Kiln field (K7) and ¼ acre of Cox and Worcester on Egham field (E31). Post-war plantings should more than make up for the loss of crop on these areas.

Routine spray programme

Little winter washing was done in the winter of 1956-57 and spring applications of insecticide proved very effective in controlling all major pests on apples and pears. Cherry Black Fly was troublesome and periodic spraying with tar oil may prove necessary. Two applications of DDT were used to control the heavy infestation of apple aphids this year. Otherwise, the pre-blossom programme for apples and pears was identical with that detailed in last year's report. Post-blossom captan was used for scab control on pears and a mixture of lime-sulphur and colloidal sulphur on apples. Scab control was satisfactory but mildew was widespread on some plantations. Two summer ovicide sprays gave good control of red spider and two applications of lead arsenate were used against Codling Moth.

Our plums were sprayed as described last year but young cherries received five Bordeaux sprays as follows : White bud 6 : 9 : 100+1½ pints DDT emulsion ; petal fall 2 : 3 : 100+6 pints cotton

seed oil ; mid August 2 : 3 : 100+6 pints cotton seed oil ; mid September 4 : 6 : 100+6 pints cotton seed oil and late October 10 : 15 : 100.

Raspberries were sprayed with 2½ gallons of lime-sulphur at bud burst against Cane Spot, and with BHC in early May against Raspberry Beetle. Black currants were sprayed with metasystox against aphids and midge and non-fruiting bushes with endrin against Big Bud Mite. Fruiting strawberries were sprayed with a mixture of 2 gallons of lime-sulphur and 12 oz. of metasystox at the end of April and sulphur dusted before picking as necessary. After picking they were again sprayed with metasystox and, when the beds had been cut over and cleared up, two further sprays of lime-sulphur were given as mildew was troublesome.

Arable crops

The large planting programme undertaken in 1955-56 considerably reduced the area of open ground, and only 109 acres were available for arable crops in 1956-57. This smaller acreage combined with the effects of the bad harvest considerably reduced the returns from arable crops.

Potatoes.—Nine acres of Craig's Royal were planted early, on land previously cropped with cocksfoot, and grew and yielded well. Of this area, 6 acres from once grown seed were lifted in August and averaged 9 tons per acre and the rest grown from Irish seed were barn stored in October, so that the seed could be saved. Six and a half acres of Majestic were planted rather late on some of the heavier soil where it was exceedingly difficult to make a seed bed. However, they did reasonably well and approximately 11 tons per acre were harvested.

Peas.—Twenty acres of peas were grown altogether, 10 acres of Perfected Freezer and Kelvendon Wonder for quick freezing and 10 acres of Lincoln and Surprise for canning. The prolonged spring and early summer drought proved disastrous, germination was slow and growth poor and the bine was so short that harvesting was difficult. Yields, 23 cwt. per acre on the average, were only just over half those of the previous season.

Cereals.—Yields were most disappointing and the wet August made harvesting difficult. However, the acreage was small and only a little grain had to be dried. Twenty-three acres of wheat were grown : 11½ acres of Banco, 5½ acres Svenno, and 6 acres Cappelle. The Cappelle again averaged 6 qr. per acre but the Banco only just over 4 qr. The Svenno, which was spring planted after grubbed experimental plots of soft fruit, also gave 4 qr. per acre. Seventeen acres of Proctor barley were planted in the spring and yielded 6 qr. per acre ; 4½ acres of Blenda oats are not yet threshed.

Of the 15½ acres of 1-year ley, 8 were made into silage and the rest into hay. Yields were not heavy but the weather was ideal and some excellent hay was made. Four-and-a-half acres of cocksfoot were sown for seed production but slow germination due to lack of rain resulted in a very weedy plot which required two sprays of DNBP to give a good clean stand.

Thirty-six Devon steers were again wintered and did exceptionally well. Some were sold direct to the Fatstock Marketing Corporation and the rest at Maidstone May Fair.

Experimental nurseries

The 1957 maiden tree nursery was not quite as large as in the previous season. Nevertheless a total of 11,669 one and two year old trees were lifted, comprising 6,518 apples, 972 cherries, 2,267 pears and 1,912 plums. In addition, smaller numbers of a range of varieties of soft fruit bushes and strawberry plants were also raised. A further seven varieties were added to the range of mother trees available—Merton Beauty and Sunset apples, Governor Wood and Frogmore cherries, and Conference, Beurré Hardy, and Dr. Jules Guyot pears. Because of the mild open weather, leaf fall was slow and lifting of the main bulk of nursery stock could not begin before 28th October. However, the good weather continued, and in spite of the late start, all trees were up by 9th December and most orders for trees and rootstocks for other research institutes and of surplus material for Members were despatched before Christmas.

Established plants were little affected by the spring drought, and maiden growth was good, but poorly rooted rootstocks planted back in the spring for growing on and cuttings suffered. Strenuous efforts will be made to get these in earlier in future.

A total of 351,171 shoots were harvested from the stoolbeds of which 103,325 were fit to line out for budding. Rooting was good but the length and diameter of the shoots was a little disappointing in some cases. Repeated routine spraying with lime-sulphur kept mildew under control and other pests and diseases gave little trouble.

Experimental glasshouses

Renewals and modifications in the virus houses have been continued. As metallic gauze weathers and becomes dirty the movement of air is restricted ; this is especially important where ventilation is

mechanical, since the efficiency of the system is determined largely by the ease of air flow out of the glasshouse. Air outlets adjacent to some of the warmest compartments have been regauzed with phosphor-bronze and P.V.C. gauze ; the latter has the advantage of transmitting more light and may be cleaned, consequently the size of aperture should not decrease appreciably.

The area of these outlets has been increased by fitting both types of gauze in removable frames placed horizontally at the base of the lantern apex. In addition, a number of new gauzed outlets leading to the base of the lantern apex have been made from some of the smaller compartments.

P.V.C. blindcloth is being tried as a means of shading on the sides of the virus glasshouses instead of fabric blinds, which do not last for more than a few years because of excessive wear and tear caused by damp and wind.

To reduce the labour involved in watering small pots during the warmest days, some benches and part of the floor in one glasshouse have been adapted for semi-automatic watering ; this has been satisfactory from the watering point of view but it has not been easy to remove surplus water and the system will be modified before next summer. The old gauze house for raising strawberry runners has been removed and rebuilt in line with other glasshouses ; roof ventilators have been fitted and new gauze used throughout.

A new 20×10 ft. timber and aluminium glasshouse has been built for experiments with Apple and Pear Scab. This house has large panes of glass and is orientated approximately east-west to admit the maximum amount of winter sunlight ; supplementary illumination is provided to enable potted trees to be grown during the shortest days. Ventilators are gauzed to keep out insects and artificial heat is supplied from low pressure steam controlled by a thermostat. During the summer three cooling units maintain a temperature of 70° to 75° F. on all but the hottest days. A small bench in a glasshouse adapted for mist propagation has given interesting results. Very fine nozzles and a soil warming cable, giving a temperature of about 70° F. in a mixture of 50 per cent sand and peat have enabled loganberry and *Rubus henryi* leaf-bud cuttings and soft-wood cuttings of various plants to be rooted in from four to eleven weeks.

The partial control of temperature under glass by limiting the solar radiation with heat absorbing glass has given temperatures about 11° F. below those in an unshaded house of similar design.

Apple and pear trees have been forced and seeds germinated as in previous years. In addition, small numbers of various plants have been grown during the winter. The number of trees, root-stocks, seedlings and strawberry plants is still very large but has not been increased appreciably.

Part II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By W. S. ROGERS

A very early blossom season and late spring frosts, combined with poor fruit setting conditions, led to light crops on many plots. Pears and plums suffered badly, but fair to good crops of apples were harvested. On our low-lying 'frost plot' successful automatic control of frost by water sprinkling was achieved (see p. 10).

A notable activity was the holding of the second Pomology Course for overseas research workers, in collaboration with the British Council. This provided an opportunity for reviewing much of our recent research work; and for making or renewing valuable overseas research contacts.

Twenty-five papers were published during the year (see p. 10).

Tree fruits

The area of Pomology field trials has risen to 90 acres, and we also record 16 acres of trees of the Fruit Nutrition Section.

Rootstocks

A general review on stock and scion relations, paying particular attention to the part played by root and stem, and to possible mechanisms of rootstock effect, was published (E.472).

An anchorage trial of Cox's Orange Pippin on M.II and MM.104 was planted on a grower's farm in a windswept site in Sussex, comparing trees staked at planting with others left unstaked. The trial is designed to show if trees on the well-anchored MM.104 will do well without staking; and whether trees that had stakes during the first seven years are less stable, when the stakes are removed, than trees that had had none.

Six of the M.IX Cross apple rootstocks, worked with Cox's Orange Pippin, have been under trial as cordons for the past eleven years. Four are more dwarfing than M.IX and two more vigorous, but none has shown a significantly greater cropping capacity.

Rootstock and cultural trials of cherries, on selected mazzards, have been planted on some 10 acres of Newgates Field. The main trial consists of the varieties Merton Bigarreau, Merton Glory and Géante d'Hedelfingen on the rootstocks F1/3, which has proved distinctly weaker in growth in the nursery than other mazzard clones, and F12/1 the well known vigorous rootstock. Two subsidiary trials, of Early Rivers, include comparisons of rootstock F5/4, of moderate vigour, with F12/1, and of bush (3 ft. stem) trees with standard (6 ft. stem) ones.

The cherries are interplanted with plums, including a trial of Victoria on Myrobalan B and Brompton, and of Ontario worked high (4 ft. 6 in.) and low (5 in.) on Myrobalan B.

The cultural treatments will include different soil management systems and nutritional levels; but the trees will receive uniform fertilizers and clean cultivation for about the first five years. The plums are regarded as filler trees, and will be removed as soon as the cherries need the space, probably in fifteen to twenty years.

Records were maintained on the older rootstock trials. From some 1,500 plants raised from seed of St. Julien plum, about 40 clones have been isolated for testing as rootstocks. The clones were raised from plants that had already flowered, and so were no longer juvenile. Characters examined included suitability of nursery habit, ease of rooting from cuttings and freedom from disease. Tests for compatibility with plums and peaches are in progress.

The effect of different soil temperatures on rootstocks has been assessed by growing maiden trees of Cox's Orange Pippin on M.IX, II, and XVI in soil heated to 75° and 85° F. during the four summer months, compared with unheated controls. The results, which are being prepared for publication, indicate that 85° F. has no adverse effect on growth of any of these rootstocks.

An investigation was begun by a postgraduate worker of possible ways of measuring the rate of

auxin destruction in different apple rootstocks. Preliminary results suggest that pieces of both stem and root bark can inactivate indoleacetic acid in solution and that different rootstocks differ in their ability to do so.

Incompatibility

A 9-year-old incompatibility trial of double-grafted pears on quince rootstock has been terminated; a paper is in the press.

An investigation has been begun in collaboration with the Biochemistry Section to examine biochemical changes occurring at or near incompatible unions during the year. An attempt will be made to correlate such changes with developments in the anatomical structure of the union in the same trees.

In collaboration with the Plant Pathology Section the compatibility of Williams' pear from three different sources was examined, and marked differences were found in their degree of compatibility with Quince A rootstock. Further work is in progress on various biochemical aspects of this material.

A survey has been made of the ability of different pear varieties to liberate hydrocyanic acid from amygdalin solution, since this reaction is believed to be one of the main causes of pear/quince incompatibility in some countries. Two new aspects of this work, (1) the effect of the previous day's temperature and (2) the action of a water soluble inhibitor which appears to play a major part in controlling the rate of the reaction, were studied.

Trees of the plum variety Oullins Golden Gage, from three sources, budded on Myrobalan B, Wibaut's Myrobalan (from Belgium) and Myrobalan 29 (from the U.S.A.), were weighed and broken at the union when two years old. Only the trees on Wibaut's Myrobalan had sound unions comparable with the compatible combination Oullins/Brompton.

Three pear varieties budded on *Pyrus calleryana* seedlings have shown signs of incompatibility when three years old.

A paper on double-shield budding was published (E.439).

Histology

The relation of structure of the cortex and periderm of apple shoots to their resistance to the Woolly Aphid (*Eriosoma lanigerum* Hausm.) is being studied in collaboration with the Entomology Section. Both seedlings from crosses with resistant parents, and scion varieties of known degrees of resistance and susceptibility are being examined.

Detailed records are being made of the root structure of (1) the Malling-Merton rootstocks, with controls from the Malling series, (2) the rootstocks M.XVII to M.XXV, and (3) a family of apple rootstocks bred in British Columbia. Differences in the length and width of root hairs of apple rootstocks are also being recorded.

The stem structure of interstocks is being examined in relation to the influence of the interstocks on the growth of apple trees.

Roots from a plum stock-on-stock trial have been preserved for a study of scion influence on root structure. In collaboration with the Physiology Section roots from an apple stock-on-stock trial have been preserved.

Leaves of apple rootstocks have been sectioned for a study of leaf structure in relation to the growth of unworked plants.

In collaboration with the Plant Pathology and Biochemistry Sections a method has been found of removing the epidermis from apple leaves in a state suitable for biochemical assay. A preliminary examination was begun of histochemical changes occurring in the leaf epidermis during development.

Further work has been done on the histology of plums affected with bark split virus.

Propagation

A first batch of cherry seedlings, arising from crosses designed to provide more dwarfing rootstocks, has been established for propagation and nursery tests. Hedges of virus tested clones of apple and plum rootstocks are being grown to provide cuttings for experiments. Fourteen plum rootstock clones are being examined for their stem building properties.

Investigations in collaboration with the Physiology Section were continued. The paper on the interplay of factors influencing rooting behaviour of shoot cuttings, given at the 14th International Horticultural Congress, was published (E.438). Root cuttings from plants of a single clone, but of different age of establishment, showed that cuttings from younger plants root best (see page 57).

Additional clones are being included in long term experiments with cuttings ; the apple rootstocks M.II, M.VII and MM.104 and the plum rootstocks St. Julien A and Pershore all responded well to the hardwood cutting method.

Experiments with leafy cuttings under intermittent mist were continued and the problems

associated with transference of rooted cuttings to the open nursery are being investigated. Two papers describing the experiments of 1956 with apple rootstock cuttings are in the press. In these papers the mist technique is compared with the traditional closed propagation frame : the main advantage of mist is the prolonged healthy state of the cuttings, enabling rooting to develop. With leaf-bud cuttings, success in the closed frame depended on rapid rooting, favoured by bottom heat.

Root studies

The entire root-systems of six 10-year-old trees of Cox on M.VII were excavated as part of a study, in collaboration with the Fruit Nutrition Section, of the effect of soil management on root development. Three treatments were investigated—clean cultivation, grass sward and straw mulch. Differences were noted in the depth of rooting and in the amount of fibre produced at different levels. The data are being prepared for publication.

Pruning

A report on pruning trials with the apple Laxton's Superb was published (E.478). Established-spur pruning lessened the biennial bearing habit and gave better sized fruit than renewal-pruning and regulating, in this variety.

A pear pruning trial was planted, including Doyenné du Comice, Conference and Beurré Hardy on Quince A. The pruning methods include some designed to secure early and regular bearing.

Fruit thinning

The thinning trial with the apple Sunset, in collaboration with the Plant Physiology Section, was vitiated this year by frost damage.

Analysis of fruiting

Because of the spring frosts, experiments on fruit setting have been postponed until next season. Studies on the development of the flowers, especially the number and fertility of ovules during the pollination period have been started.

Biennial bearing

The first year's results of defoliation of whole trees at different times during the ' off ' season confirmed those of an earlier experiment using only parts of trees. Fruit bud formation was greatly reduced by total defoliation after the end of May, but there was marked variation in intensity of flowering along different branches within individual trees.

The trial in collaboration with the N.A.A.S. on the use of copper sulphate as a defoliating agent gave good results, and a second trial has now been started. Together with the Physiology Section a study is being made of the nature of injury due to copper sprays and the relation of this to the subsequent growth and cropping of the trees. The results of the trials for the first two years are being prepared for publication.

A trial of naphthalene acetamide as a blossom thinning agent was vitiated by frost, but records have been made on the effect of the spray upon leaf growth and bud development.

Breeding

Rootstocks.—Four of the Malling selected Mazzards (*Prunus avium*) have been selfed and intercrossed with the object of producing cherry rootstocks with a dwarfing influence. In spite of self incompatibility in several of the parents, about 1,700 seeds have been obtained. Some seedlings from crosses between the Mazzards and related *Prunus* species of dwarfing habit are undergoing tests as rootstocks.

Fruits have been obtained from a cross between Beurré Superfin pear and the Angers quince ; and the hybrid seedlings, when obtained, will be tested for suitability as pear rootstocks. Seedlings from pear/apple hybrids, now 2-3 yrs. old, are still under observation.

Scion varieties.—A paper is published on p. 68 dealing with the breeding of late flowering apples. This year eighteen families were raised by crossing Cox's Orange Pippin, Court Pendu Plat, Crawley Beauty and Edward VII with pollen of selected varieties, and twelve families from self-pollinations. Some 10,000 seedlings, planted out during the spring of 1956, have been classified on their season of leaf break.

Work in collaboration with the Entomology Section on the raising of apple seedlings resistant to Woolly Aphid has continued. Since 1950 about 3,000 seedlings have been raised from crosses in which one or both parents were resistant and, of these, about one-tenth have shown a high degree of resistance. They are being grown on for fruiting.

A final selection of promising seedlings is being made from families raised to provide new varieties of good fruit quality and extended season.

Varieties

Following very heavy crops last year plum blossom was light in many varieties. The spring frost, and other unfavourable factors including prolonged cold winds in late spring, destroyed many fruitlets and yields of most varieties were poor. Nineteen-year-old trees of Severn Cross gave 170 lb. per tree, whereas 22-year-old trees of Marjorie's Seedling and Bountiful, and 19-year-old trees of President averaged 30 lb. per tree. In the gage and plum variety trial, now twenty years old, Comte d'Althann's Gage gave 100 lb., Warwickshire Drooper 70 lb., Victoria 40 lb., and Ontario 30 lb. per tree. Other varieties gave only very light crops.

A new plum variety trial has been planted, including Laxton's Delight, Severn Cross, Anna Spath, Merton Gage 1645 and Victoria, on Brompton.

Reports were published on a dessert apple variety trial (E.465), and on blossoming periods of some apples, pears and plums (E.466).

Calibration area

An area of $2\frac{1}{2}$ acres was planted with pears, at 15 × 15 ft. spacing. The growth of the trees will be calibrated before the plot is used for other trials. The main varieties are Conference and Williams' Bon Chrétien ; Laxton's Superb, Packham's Triumph, Bristol Cross, Gorham and a strain of Doyenné du Comice reported to be regular bearing, have been included in the guard rows. All the trees are on Quince A ; Williams' Bon Chrétien, Packham's Triumph and Bristol Cross were double shield-budded with Beurré Hardy.

Small fruits

The small fruit trials, including calibration areas, now cover about nine acres.

Variety and strain trials

Strawberries.—In the trials comparing heat treated and untreated clones, vigour differences were again in favour of the treated clones, particularly Cambridge Favourite. The treated clones of Huxley, Perle de Prague and C. Favourite yielded more heavily than the untreated clones ; but in Early Cambridge and C. Rearguard the treated clones yielded much less than untreated, owing to reduced blossom development apparently associated with excessive vigour in these varieties (see p. 50).

A new clone of Royal Sovereign, M.415, has been released to the Nuclear Stock Association for propagation. Its yield this year was over 40 per cent greater than that of the present Special Stock clone, M.48 ; and in three trials (eight crops) the average increase was about 15 per cent. The clone M.415, selected from plants from Ireland, shows no botanical difference from M.48, and there is no difference in appearance or flavour of the fruit. The increase in yield comes in the main and later picks, rather than in the earlier ones.

A new trial of clones and varieties includes Talisman with and without latent virus, Merton Princess, Royal Sovereign, Sir Joseph Paxton and Sutton Valence.

Loganberries.—The trial of five new virus-tested Loganberry clones has yielded its first crop. The performance of four of these clones so far is very promising, and at least equal to that of the best clone grown at East Malling in earlier trials.

Raspberries.—A final disease survey, made before three variety trials were grubbed at the end of 1956 showed a marked increase in Spur Blight and an equally marked decrease in *Botrytis* attack. Seedlings T and H and Lloyd George again showed relative resistance to Spur Blight while Malling Promise, Exploit, Enterprise and seedlings V, W, Y, Z, 51/47, and 51/35 were heavily attacked. Lloyd George and seedlings H and T again showed low percentages of canes attacked by *Botrytis*, whilst Promise, Exploit, Norfolk Giant and V showed the highest percentages of infected canes.

Average yields in Trial N4c, for 1947 to 1956 inclusive, were Promise 76·6 cwt. per acre, Exploit 76·2, Norfolk Giant 49·9 and Newburgh 47·4 ; seedling T yielded 77·9 but none of the seven other seedlings in the trial was considered worthy of further test. Average yields in Trial N4h for 1949 to 1956 inclusive, were Promise 74·0, Enterprise 56·2, Norfolk Giant 46·5 and seedlings 51/47 and T 76·6 and 74·4 respectively. Three other seedlings in this trial all yielded poorly. The yield and quality of seedling T make further trial of this type desirable ; seedling 51/47, although a high yielder, is difficult to pick and is inferior in other ways to its sister variety Malling Promise.

The third trial, N4j, included the New Zealand and Amos strains of Lloyd George, with Promise and Exploit as controls. The New Zealand stock outyielded the Amos clone consistently over the first six years, but in each of the final two years of the trial the position was reversed. Average yields

for the two were 66·5 and 61·5 cwt. per acre respectively, Promise and Exploit having given 65·5 and 62·7. In recent years much of the fruit of Lloyd George was too small and crumbly to be of commercial quality, however, owing to virus infection.

Black currants.—In our small variety collection, sun-scald was observed on exposed fruits at the end of June ; Westwick Choice and Wellington XXX were most affected.

Propagation and maintenance of stocks

Strawberries.—Over 60 virus-tested clones have been maintained in insect proof houses. Isolated runner beds have been used for propagation of plants for fruiting trials.

Loganberries. –Plants from a Loganberry clone selected at East Malling in 1932, and later grown at Long Ashton, were found to be free from a virus related to decline in this fruit. A reselected clone raised from one of the tested plants was further multiplied at Long Ashton by intensive methods, and then handed to the Nuclear Stock Association for propagation and introduction to the industry.

Blackberries.—Preliminary tests of the Thornless Evergreen Blackberry made by the Plant Pathology Section have not revealed the presence of any virus diseases. Plants are being raised for a field trial pending the completion of the virus tests.

Breeding

Small fruits.—Breeding of raspberries resistant to the *Rubus* Aphid (*Amphorophora rubi*) was continued in collaboration with the Entomology Section ; a paper on the genetics of this resistance is being published elsewhere. The inheritance of the characters ' tip rooting ' and ' suckering ' in the raspberry has been investigated and the results prepared for publication. An account of other work in progress appears on p. 62.

Cytology.—The study of meiosis in inter-species *Ribes* hybrids is continuing ; a résumé of cytological work is published on p. 75.

Cultural measures

Strawberries.—A small trial of the Hill-mat matted row system was planted with the variety Talisman. Because of its habit of forming very numerous crowns, Talisman may be less suitable for matted rows than some other varieties.

Trials of nitrogen and irrigation were continued.

Weedkillers

Work with weedkillers is being extended using chemicals already known to be toxic to particular weeds, and paying special attention to the effects on the fruit plants themselves.

Strawberries.—The weedkiller 2,4–DES, applied at 3 lb. per acre monthly during the summer, plus DNBP amine at 2 lb. per acre in autumn gave promising results, and caused no appreciable harm to Royal Sovereign plants.

Black currants.—MCPB, which is promising for the control of bindweed (*Convolvulus arvensis*) was applied to black currant bushes at 2, 4, and 8 lb. per acre after picking. The effects on growth and yield will be studied.

Raspberries.—Preliminary trials, similar to those on black currants, have been started.

Frost damage investigations

A radiation frost during the night of 5th/6th May (screen minimum 28° F. grass minimum 22° F.) caught most fruit trees in the very vulnerable petal-fall or young fruitlet stages. Damage varied according to site, being in general light on the higher plots, and increasing to a wipe-out on the lowest one, the ' Frost Plot ', although the screen minimum here was only 1° F. lower than on the meteorological plot in the upper part of the Station. This gradation of damage was obvious also on individual trees, which later had their lower branches bare and the higher ones weighed down by a heavy crop.

On the ' Frost Plot ', pears and plums were most seriously damaged but some varieties, e.g. Bristol Cross pear, and Pershore plum, gave a small crop. Apples were also severely damaged, only the late flowering variety Crawley Beauty, which was in the pink bud stage at the time, escaping. Some varieties, e.g. Laxton's Superb and Edward VII cropped in spite of heavy damage. Cherry fruitlets, particularly those of Frogmore were less severely damaged. The yield of early strawberry varieties, e.g. Mme. Lefebvre, was reduced. The late flowering varieties Rearguard and Vigour with their blossoms sheltered by the abundant foliage were little damaged. The most advanced buds of raspberries were killed and the gooseberry crop was reduced mainly in the varieties Leveller and Green Gem. Black currants were little damaged because of their advanced stage of development and the dense foliage sheltering the fruitlets.

On higher land many apples were blemished and some misshapen, owing to the frost. Most

varieties showed heavy russeting with cracks round the pedicel, frosted cheek, frost rings, or green blotches round the eye. In the variety Tydeman's Late Orange the cork formation was so severe that much of the fruit was useless. Howgate Wonder and Bramley's Seedling were, however, outstanding by their lack of frost blemishes.

Detailed field studies were made of frost damage on about a hundred varieties of various fruit plants and 172 apple seedlings ; and of the effects of ten rootstocks and four pruning treatments on apple, of silver leaf on plum, and of manganese and iron deficiencies on raspberry, in relation to frost damage.

Investigations on the effect of watering the soil before a frost again demonstrated the improved heat conduction through the surface layers of the soil, giving a slightly higher temperature over wet soil than over dry.

Experiments were carried out using different materials to cover strawberry plants at night. Sisalkraft paper covered with aluminium foil, either on both sides or on the upper side only, gave better protection than plain paper or paper with aluminium on the underside.

Successful protection of apples from frost damage was achieved by automatically controlled water sprinkling. A range of sprinklers covering about $\frac{1}{4}$ acre was turned on thermostatically when the temperature fell to 32° F., and operated on fourteen nights commencing at the green cluster stage of Cox's Orange Pippin on 22nd/23rd March. Different sprinklers were turned off at various stages of development or on critical nights to allow the frost damage and resulting blemishes at the different stages or under different environmental conditions to be studied. Sprinkled trees carried a full crop, while unsprinkled ones bore practically nothing. The full results are being prepared for publication.

In the frost rooms two plum and three cherry varieties and seventy-five apple seedlings, were tested for frost resistance of their blossom. A parallel series of histological studies is being made.

The effect of soil moisture deficit at various stages of development upon the frost resistance of blossom of Cox's Orange Pippin was investigated, combined with histological studies and determinations of the water and total sugar content of the flowers.

Experiments were continued on physiological factors associated with frost resistance of blossoms. More information was gained on the effect of the pre-freezing temperature on the frost resistance of the blossoms and on their sugar and water contents at different stages of development.

Apple trees of the variety Crawley Beauty, growing in sand culture with different levels of nitrogen and potassium, blossomed for the first time. Freezing tests were carried out and the results related to analyses of sugar and water contents.

Microscopic studies of the mechanism of frost resistance were continued.

A paper entitled 'Spring Frost Problems in Fruit Plantations', given at the congress of the Société Pomologique de France at Namur, was published (E474).

Mycorrhiza

Attempts to establish a pure two-membered culture by inoculating sterile plants with individual germinated *Endogone* spores known to be free from internal and external contamination are continuing. A cytological study of spore germination and events immediately preceding is in progress.

Chemical analysis of mycorrhizal and non-mycorrhizal apple seedlings confirmed that infection can affect the balance of nutrient uptake in plants grown in autoclaved soil. A note has been published on the growth of such plants and on some aspects of the mineral nutrition (E476).

Walnuts

Yields were again light. The need for varieties more adapted to our climatic conditions is very evident. Various desirable characters are available in different varieties, and a breeding programme may be worth considering.

Horticultural meteorology

Wind studies in orchards, with differently spaced trees, have continued and a report was published (E454).

A prototype hail gauge has been made and is under test.

The usual meteorological records were maintained.

Publications During the Year

E438 Garner, R. J., and Hatcher, E. S. J. (1957). **The interplay of factors influencing rooting behaviour of shoot cuttings.** *XIVth int. hort. Congr.* (*Rep.*), The Hague, 1955, 204-14.

E439 [redacted] (1957). **The development of double-shield budding to overcome stock/scion incompatibility.** *XIVth int. hort. Congr.* (*Rep.*), The Hague, 1955, 1182-4.

E454 PRESTON, A. P. (1956). **Orchard tree spacing in relation to wind and cropping.** *J. hort. Sci.*, **31**, 303-6.

E457 ROGERS, W. S. (1956). **Saving costs by Hill-mat planting.** *Grower*, **46**, 766-7. *Rep. E. Malling Res. Sta. for 1956* (1957), 173-4 (under different title).

E459 GLENN, ELIZABETH M. (1957). **You don't have to prune Victoria plums.** *Grower*, **47**, 43-5.

E460 SINGH, S. M., ROGERS, W. S., and SLATER, C. H. W. (1957). **Mist propagation frames for leafy cuttings.** *Rep. E. Malling Res. Sta. for 1956*, 54-9.

E461 GARNER, R. J., and HATCHER, E. S. J. (1957). **Rootstock effect on the regeneration of apple cuttings.** *Rep. E. Malling Res. Sta. for 1956*, 60-2.

E462 ———, and NICOLL, CATHERINE P. (1957). **Observations on *Prunus cerasus, P. mahaleb* and other species as rootstocks for sweet cherries.** *Rep. E. Malling Res. Sta. for 1956*, 63-72.

E463 KNIGHT, R. L., and KEEP, ELIZABETH (1957). **Fertile black currant—gooseberry hybrids.** *Rep. E. Malling Res. Sta. for 1956*, 73-4.

E464 TYDEMAN, H. M. (1957). **A description and classification of certain plum rootstocks.** *Rep. E. Malling Res. Sta. for 1956*, 75-80.

E465 PRESTON, A. P. (1957). **Growth and cropping of some new dessert apples.** *Rep. E. Malling Res. Sta. for 1956*, 81-4.

E466 ——— (1957). **Summer gale damage to apple rootstock and pruning trials in 1956.** *Rep. E. Malling Res. Sta. for 1956*, 85-8.

E467 GLENN, ELIZABETH M. (1957). **Blossoming periods of some tree fruits at East Malling.** *Rep. E. Malling Res. Sta. for 1956*, 89-90.

E468 WILSON, DOROTHY J. (1957). **Thirty-six-year-old trees of Conference pear on Quince rootstocks.** *Rep. E. Malling Res. Sta. for 1956*, 91-2.

E469 SLATER, C. H. W. (1957). **Frost damage research equipment at East Malling.** *Rep. E. Malling Res. Sta. for 1956*, 93-6.

E470 TROWELL, G. F. (1957). **Weather conditions during 1956.** *Rep. E. Malling Res. Sta. for 1956*, 97-100.

E471 ROGERS, W. S., and WILSON, DOROTHY J. (1957). **Strawberry cultivation studies. IV. Developments in matted systems.** *J. hort. Sci.*, **32**, 99-107.

E472 ———, and BEAKBANE, A. BERYL (1957). **Stock and scion relations.** *Ann. Rev. Plant Phys.*, **8**, 217-36.

E473 MODLIBOWSKA, IRENA (1956). **Les problémes des gelées printanières dans les plantations fruitières.** *L'Arboriculture Fruitière*, **33**, 9-13.

E474 ——— (1957). **Le probléme des gelées printanières et la culture fruitière.** *87e Congrès Pomologique International, 1956*, 83-114.

E475 ROGERS, W. S. (1957). **Protection from spring frosts.** *Grower*, **47**, 984-5.

E476 MOSSE, BARBARA (1957). **Growth and chemical composition of mycorrhizal and non-mycorrhizal apples.** *Nature*, Lond., **179**, 922-4.

E478 PRESTON, A. P. (1957). **Pruning trials with Laxton's Superb apple.** *J. hort. Sci.*, **32**, 133-41.

E479 Tubbs, F. R. (1957). **The control of the vegetative growth and reproduction of perennial plants.** *XIVth int. hort. Congr.* (*Rep.*), The Hague, 1955, 39-50.

E482 KNIGHT, R. L. (1956). **The genetical approach to disease resistance in plants.** *Emp. Cott. Gr. Rev.*, **33**, 191-6.

II. STATISTICS AND RECORDS

By T. N. HOBLYN and S. C. PEARCE

Design and analysis

The advisory work of the Section has continued at much the same level as in past years. Fifty-seven experimental designs were prepared for the Research Station, fourteen for N.A.A.S. Experimental Horticulture Stations, and four for other N.A.A.S. experiments. The number of analyses of data, though still high, fell to 746, partly because no theses were in preparation. On September 30th, 1957, the number of analyses awaiting attention was 131, by far the highest figure in the history of the Section for the time of year ; this was a result of the ever increasing flow of data from the Plant Analysis Section.

Use of land on the Experimental Farm

It is now several years since there became available any land that had not previously been used experimentally and was suited to fruit-bearing trees. Nowadays the choice of land is very limited and the size and shape of that which is available often colour the project and the statistical design to a large extent. During the coming 5 years, only 33 acres of fruit land are likely to be ready for replanting and, of this, 9 acres have already been allocated. This means that many experiments have to be considered 2-3 years before planting and that programmes have sometimes to be curtailed if experiments are to be fitted into suitable land without reducing essential replication.

In this Section the statistical design and analysis of experiments is the primary concern, but, in long term trials, there are many other non-statistical matters that are not always remembered. Some of these are detailed on p. 43.

Statistical research

Methods of experimental design and analysis

During the year some progress has been made in ' seeing the plant as a whole '. If analyses are carried out separately on girth, blossom counts, crop, etc., no information is obtained about the relationship between these quantities. Thus, if for example, a certain treatment increased growth, and fruiting was thereby increased but not proportionately, there would be no means of detecting this unless each analysis separately gave a clearly significant result. Consideration has therefore been given to methods of *factor analysis*, largely developed for use in psychology, where the investigator may have a ' battery ' of related measurements and wishes to combine them to best advantage, and to *discriminant analysis*, developed for anthropological research, where it may be necessary to study the relationship between tribes, castes, etc., on the basis of measurements of bones from graves of known origin. Both methods have been applied to data from fruit trees with results that are most encouraging. The computing involved has, however, been so extensive as to limit the application of these methods.

A recent paper (M36) sets out a further attempt to ' see the plant as a whole '. If different parts of a tree are treated differently, it is reasonable to hope for greater accuracy of comparison of the treatments than if they had been applied to whole trees, because of the elimination of the inter-plant variation. There is, however, the risk that treatments will have an effect on parts of the tree to which they were not applied, and the published method shows how to take this possibility into account.

More mathematical aspects of design, especially with reference to the application of further treatments to plants that have already been used experimentally, are being studied. Some of these have been described elsewhere (M34, M39, M41).

The capture-recapture method of estimating insect populations has been examined, taking account of the wastage due to death and emigration from the trees under study and of dilution due to birth and immigration. For data from repeated samplings it is now practicable to make estimates of maximum precision.

Statistical methods in biology, including measurement problems

Techniques of growth analysis have been further explored in collaboration with the Plant Physiology Section, particular attention this year having been devoted to time of leafing out and leaf fall and to the effect of root trimming before planting. The development of leaf area throughout the season has been studied with a view to reducing the number of times this measurement needs to be made. Attention has also been given to the theory underlying the methods of growth analysis being developed. A paper on statistical aspects of the field use of the grid method of measuring leaf areas appears on p. 83.

Information has been sought concerning the circumstances in which calibration by trunk girth or by previous crops gives the more effective estimate of present cropping. Latterly, use has been made of factor analysis, as described above.

In studies of measurement special attention has been given to the interpretation of branch girths. Here again factor analysis has shown promise.

The method of discriminant analysis has been applied to data from one of the long-term rootstock trials in order to test the usefulness of the method in elucidating rootstock effect. The result has been to cast interesting light on the concept of vigour, which has in the past presented difficulty because no two measures of it ever entirely agree.

Field trials

In the enquiry into methods of restoring the uniformity of land, carried out in collaboration with the Fruit Nutrition Section, the mangolds, the final crop on the short-term part of the trial, have been lifted and recorded ; on the long-term part stocks were planted for the indicator apple trees.

The uniformity trial of apples completed its second three-year cycle, and was grassed down for the third. As usual at the end of a cycle some of the trees of the trial were lifted and then recorded in detail.

Publications During the Year

M27 Pearce, S. C. (1957). **Some considerations in deciding plot size in field trials with trees and bushes.** *J. Indian Soc. agric. Statist.*, **7**, 24-6.

M34 Freeman, G. H. (1957). **Some experimental designs of use in changing from one set of treatments to another. Part I.** *J.R. statist. Soc.*, B, **19**, 154-62.

M36 Pearce, S. C. (1957). **Experimenting with organisms as blocks.** *Biometrika*, **44**, 141-9.

M39 Freeman, G. H. (1957). **Some further methods of constructing regular group divisible incomplete block designs.** *Ann. math. Statist.*, **28**, 479-87.

M40 Pearce, S. C., and Greenham, D. W. P. (1957). **A short history of Research Station land in the parishes of Ditton and Aylesford.** *Rep. E. Malling Res. Sta. for 1956*, 49-53.

M41 Freeman, G. H. (1957). **Some experimental designs of use in changing from one set of treatments to another. Part II. Existence of the designs.** *J.R. statist. Soc.*, B, **19**, 163-5.

M42 Pearce, S. C., and Holland, D. A. (1957). **Randomized branch sampling for estimating fruit number.** *Biometrics*, **13**, 127-30.

III. PLANT PHYSIOLOGY

By H. W. B. BARLOW

Collaboration has continued between the Plant Physiology Section and the Research Institute of Plant Physiology under Professor F. G. Gregory, and the following report includes work of the latter's staff carried out at East Malling.

Studies of growth and form in fruit trees

Field experiments

The large-scale experiment analysing the interaction of rootstock and scion in trees made up of pairs of four rootstock varieties has been cleared ; this last sample was the fifteenth to be taken in the seven seasons of the experiment, and comprised 360 trees ; these were dismembered and recorded in detail in such a manner that, either directly or by sampling, dry weights were obtained of leaves, and of wood aged one, two, three years and older, and, in the case of 96 trees, of the roots. Various checks on the accuracy of the methods were incorporated in the sampling routine. The heaviest tree weighed 38 lb. dry (71 lb. fresh) and was made up of 70 per cent stem, 24 per cent root, and 6 per cent leaves. The detailed analysis of the results will take a long time to complete.

The experiment on the effects of very heavy and very light pruning, and of deblossoming, on the growth of four commercial scion varieties has been continued. The July gale of 1956 has by now exacted a toll of 13 out of the original 192 trees on M.IX ; trees on M.XVI were not affected. This area, which escaped the full effects of the May frost, is beginning to produce a crop ; of the trees on M.IX the Laxton's Superbs, Worcester Pearmains, and Cox's Orange Pippins averaged 7·7 lb. per tree, but the Miller's Seedlings only 0·7 lb. The trees on M.XVI flowered quite profusely in this the fourth season after planting, and certain trees carried a crop to maturity, notably some of the lightly pruned Laxton's Superbs.

An experiment was carried out in which the initial surface area and weight of rooted apple layers was varied by pruning shoots of various thicknesses to different lengths, in an endeavour to analyse the tree's response to pruning. Results indicate that one year's growth increment, irrespective of amount, is partitioned between new stem and thickening on the old stem in a ratio exactly proportional to the degree of pruning.

An experiment was mentioned last year in which different numbers of shoots were allowed to grow out from the maiden stem, the greatest growth being made where the largest number of shoots occurred ; in the second year of this experiment, trees which had been treated uniformly last year were pruned and allowed to develop various numbers of shoots in 1957. The resulting vigorous growth displayed the ability of the different varieties to produce side shoots on the current year's growth : where this occurred freely the weight increase was little affected by the number of shoots allowed to grow out, but where secondary branches were few, the increase in weight was greater with greater numbers of primary branches, as in the first year of the experiment.

A small-scale experiment on the production of wide crotch angles in young plum trees was carried out using growth substance application and leaf removal techniques. Final results are not to hand, but it seems that poor growth in the dry early part of the season may have vitiated some of the results.

Growth of young trees under particular conditions

The solution-culture method has been made considerably easier to maintain by several modifications, particularly a means of rapidly changing the solution. Fungal attack of the roots is still the main difficulty in using this culture system to compare the performance of varieties which differ in their susceptibility to attack, though some headway has been made in controlling or avoiding lethal infection. The mist-culture system was used only on a small scale this year.

Detailed analysis was carried out of the growth of three apple rootstock varieties worked together in pairs, and grown in soil in pots. In studying the Net Assimilation Rate of these composite trees, particular attention is being paid to the period of leaf senescence at the end of the growing season. The importance of making allowance for differing lengths of growing season in experiments of this type is stressed in a paper in this Report (p. 101).

Further investigations were made of the source and magnitude of errors introduced in the estimation of total leaf areas of trees employing the grid method of area measurement with special sampling techniques.

Growth of individual shoots

The gale of July 1956 was mentioned in last year's Report as causing much leaf damage ; a study of the growth of leaves during that season appears in the present Report (p. 96), and shows that the check to leaf expansion was largely accounted for by the associated low temperatures. Another paper (p. 91) also stresses temperature as an important factor controlling internode extension in stoolbed shoots. This year intensive observations were made of leaf and internode growth on such shoots, to determine more precisely the part played by climatic factors in shoot growth.

Work has continued on the field apparatus for measuring carbon dioxide exchange in apple leaves over short periods ; many practical difficulties have been encountered, not all of which have yet been surmounted.

Carbohydrate reserves

Work on determining the part played by 'reserve carbohydrates' in the economy of the tree began this year with an extensive review of the literature. This revealed, in particular, the need for detailed study of the amount and location in the tree, not only of sugars and starches, but of hemicelluloses and glucosides. Analytical procedures have been worked out, and a start made on a series of samples of bark and wood from a set of six-year-old apple trees being grubbed at monthly intervals, in collaboration with the Plant Analysis Section. Experiments have been carried out on a technique which will allow serial samples to be taken from one tree without adverse effects.

Natural growth substances

It was mentioned last year that a large extract of Myrobalan B layer-bed shoots had been prepared, from which a substance strongly inhibitory to coleoptile section growth was obtained by chromatographic separation. This material has been found also to inhibit the extension of cress and radish roots, but had no effect on tomato shoots when painted on the tip or injected through a petiole. Abscission of petioles was not inhibited, nor was the curvature of coleoptiles due to unilaterally applied growth promoter. The inhibitor does not reduce the deleterious effects on coleoptile sections of very high concentrations of the growth promoter β-indolylacetic acid.

Preliminary work has been carried out in collaboration with the Biochemistry Section on the identification of this inhibitor, and, to ensure adequate supplies for this and other work, further bulk extracts have been made, not only of Myrobalan B shoots, but also of Brompton, Crab C, M.II, M.IX and M.XVI. Many technical difficulties have been met in the course of chromatographic separation of the main growth promoters and inhibitors present in these extracts, but they are gradually being overcome.

The need to relate the growth substances obtained by extraction of plant tissues with those diffusing from cut surfaces into agar has long been recognized ; an experiment this year, in which chromatograms were run of diffusates and extracts from stems, suggested that only growth promoters move into the agar, while both they and inhibitors are extracted by ether.

Vegetative propagation

Investigations of propagation methods and their underlying physiology continued in collaboration with the Pomology Section.

Hardwood cuttings of four plum (Myrobalan B, Brompton, St. Julien A and Pershore) and four apple rootstock varieties (Crab C, M.II, M.VII and MM.104) were taken in October and November, and stored during the winter at not less than 45° F., with or without an initial two weeks at 65° F. The cuttings were transferred to the nursery bed at a single time in the spring when conditions were favourable ; this is the critical stage in this propagation technique, and is being examined in this experiment.

Other trials were concerned with size of cutting, source factors, and the use of winter storage methods for Quince A cuttings, and for apple root cuttings. A long-term experiment with Crab C root cuttings has been concluded (p. 57).

The ' concentrated growth substance dip ' used here for many years is made up in ethyl alcohol ; the use of more readily available industrial solvents is desirable, and three have been examined this year : *iso*-propyl alcohol, ethylene glycol, and methylated spirits.

' Mist propagation ' of softwood cuttings (described in last year's Report) has raised several questions of practice. Experiments have been run to investigate those concerning transference to the nursery, the use of bottom heat in the frame, and growth substance treatment.

Abscission

The study of the effect of very early thinning on the natural shedding of fruit being carried out with the Pomology Section, was interrupted this year by the severe frost in May ; virtually no crop was set.

Spray damage

Attempts were made to reduce the amount of scorch produced by copper sulphate on apple leaves by supplying them with various chelating agents. Most of them were ineffective at low dosages, and protected the leaf against copper only at concentrations at which they were themselves toxic. One exception, however, is being studied further. During this investigation modifications in the method of measuring scorch were found to be necessary.

A trial was undertaken in collaboration with the Pomology Section on a farm in Sussex, of the use of copper sulphate as a defoliant in the control of biennial bearing in apples. This provided a valuable opportunity for testing on a field scale the findings of the intensive experiments so far undertaken. It was found that the small-scale method of estimating scorch slightly exaggerates the amount of scorch to be expected from spraying a whole tree instead of only a few of its leaves. The records from this trial will enable a comparison to be made of the subsequent growth of trees which suffered leaf scorching to different, but measured, degrees.

Publications During the Year

F89 Barlow, H. W. B., Hancock, C. R., and Lacey, H. J. (1957). **Studies on extension growth in coleoptile sections. I. The influence of age of coleoptile upon the response of sections to IAA.** *Ann. Bot. Lond.*, N.S., **21**, 257-71.

F90 Barlow, H. W. B., and Hancock, C. R. (1956). **Growth of leaves of an apple rootstock.** *The Growth of Leaves*, Butterworths, London, 107-18.

F91 Hatcher, E. S. J., and Garner, R. J. (1957). **Aspects of rootstock propagation. IV. The winter storage of hardwood cuttings.** *Rep. E. Malling Res. Sta. for 1956*, 101-6.

F92 Maggs, D. H. (1957). **A photometer for estimating the area of samples of detached leaves.** *Rep. E. Malling Res. Sta. for 1956*, 107-8.

F93 Llewelyn, F. W. M. (1957). **Measurements of experimentally induced copper damage in apple leaves.** *Rep. E. Malling Res. Sta. for 1956*, 109-13.

F94 Turrell, F. M., and Bentley, L. E. (1957). **Buffer capacity and pH of tissue fluids of leaves of sulphur-resistant and sulphur-shy varieties of apple (*Pyrus malus* L.) and gooseberry (*Ribes grossularia* L.).** *Rep. E. Malling Res. Sta. for 1956*, 114-24.

F95 Bird, I. F., and Ruck, H. C. (1956). **Comparative physiology of apple rootstocks. II. The effect of pH and aeration on the growth of Malling apple rootstocks in water cultures.** *Ann. Bot. Lond.*, N.S., **20**, 553-62.

F96 Llewelyn, F. W. M. (1957). **The scorching of apple leaves by copper sulphate.** *Ann. appl. Biol.*, **45**, 376-84.

F98 Vyvyan, M. C. (1957). **An analysis of growth and of form in young apple trees. I. Relative growth and net assimilation rates in 1- and 2-year-old trees of the apple rootstock-variety M.XIII.** *Ann. Bot. Lond.*, N.S., **21**, 479-97.

Omitted from 1956 list.

F81 Maggs, D. H. (1955). **The inception of flowering in some apple rootstock varieties.** *J. hort. Sci.*, **30**, 234-41.

IV. BIOCHEMISTRY

By A. N. GORROD for A. E. FLOOD

Host-parasite relationships

Continuing the work reported in previous years, the nature of the host-parasite relationships between *Venturia* spp. and apple and pear tissues has been further studied, in collaboration with the Plant Pathology Section. A technique for studying the distribution of polyphenols in various parts of leaves has been successfully developed. The ratio of total polyphenols to soluble nitrogen has been determined in leaf samples from varieties showing differing susceptibilities to infection, and promising results have been obtained.

Methods are being developed, in view of results obtained from cultures of *Venturia* spp. in the presence of analogues of caffeic acid, whereby the fate of such polyphenols in the metabolism of the organisms may be determined.

Metabolism of the apple tree

Work has recently started, which it is hoped will lead to an increase in our knowledge of the biochemistry and metabolism of the apple tree and have bearing upon research in the Physiology Section on factors influencing the energy reserves of the tree in relation to cropping.

Publication During the Year

K105 Flood, A. E. (1956). **The development of chromatography.** *Sci. Hort.*, 12, 110–17; *Rep. E. Malling Res. Sta. for 1956* (1957), 179–83.

V. FRUIT NUTRITION

By D. W. P. GREENHAM

Nutrient supply

Long-term manurial trials

In the long-term trial on Plot C2 in which trees of Cox's Orange Pippin on M.XII have received different applications of nitrogen, phosphorus, and potassium ever since they were planted in 1931, the effect of grassing-down half the plots in 1953 is being observed. The total weight of crop so far has been reduced by grassing-down in the absence of nitrogen applications, even though the swards of those plots are rich in clover. On the plots receiving nitrogen applications, however, grassing-down has caused no such reduction ; the annual application to these plots since 1953 has been 6 cwt. per acre of sulphate of ammonia, and this has greatly reduced the clover content of the swards. Fruit colour has been better on the grass plots, even where nitrogen is added, than on the plots still under cultivation.

The trees escaped serious frost damage in 1957 and carried their heaviest crop since 1954. The fruit from each tree was graded into a number of categories in order to provide more detailed information than has previously been available on the effects of manurial treatments with and without grass swards on fruit size. The effects of all the treatments in this trial on the storage quality of the fruit form the subject of a separate investigation (p. 35).

Field investigations on magnesium deficiency

The effects up to 1956 of spray and soil applications of magnesium sulphate in trials on magnesium-deficient stoolbeds of the apple rootstocks M.IV and MM.102 are described on p. 106. Growth was improved by spraying, and measurements made so far in 1957 show similar trends. Confirmation was obtained of the observation in earlier years that the number of shoots affected with mildew (*Podosphaera leucotricha*) was less on the plots sprayed 9 times with a solution of magnesium sulphate plus wetter than on those sprayed with water plus wetter only.

The effect of spraying with magnesium sulphate is also being studied on dwarf pyramid trees of Edward VII on M.VII. A treatment consisting of five applications of 2 per cent Epsom salt at fortnightly intervals commencing at petal fall has prevented the appearance of leaf scorch until late in each season and has increased the total weight of crop over the first four years of the trial by 50 per cent even though there has been no striking effect on growth. This result has been obtained on a variety and a rootstock both of which are known to be susceptible to magnesium deficiency, judging by the severity of leaf symptoms, on soil in which the level of ' available ' magnesium is not unduly low nor the ' available ' potassium very high. The data also show evidence of a crop increase from spraying with 0·5 per cent urea five times each season at fortnightly intervals commencing at petal fall, even though the leaf scorch was not reduced. This effect, which was not as great over the 4-year period as that due to magnesium sulphate spraying, may be due to a reduction in the drop of fruitlets.

Plans are being made for further tests of the value of soil and spray applications of magnesium on apples grown on a commercial scale, and for determining the combined effect of spraying with magnesium sulphate and urea.

Solution culture experiments

A description of the spray culture technique devised by Dr. W. A. Roach has been published (U10) and a bulletin (p. 159) has been prepared on the contribution made by spray culture experiments to the study of apple nutrition. Assessment of the data obtained in 1954-6 has helped to elucidate the effects of magnesium and iron supply on growth.

In collaboration with the Plant Analysis Section, attention is being given to the possibility of using water culture techniques for the investigation of some of the problems in fruit tree nutrition. The prevention of fungal infection is an important factor.

Soil moisture supply

Tree fruits.—The practical application of the results obtained so far in the trials on Laxton's Superb and Laxton's Fortune apples has been discussed in general terms in two papers (U9, U12). Growth effects have again been measured in 1957, but neither variety carried a normal crop.

Small fruits.—In the raspberry trial started last year to compare the effects of clean cultivation with and without irrigation and of straw mulch, supplementary water was found to increase growth and berry size in 1957.

A trial has been started to give information on the response of black currants to different soil

moisture conditions at two levels of applied nitrogen. The experimental variety is Amos Black, with guard rows of Baldwin. The 2-year-old bushes were cut down to 1 in. after planting in November 1956 and an overall application of water was given in May to prevent the dry spring from having a detrimental effect on the establishment of the bushes. The differential water treatments, started in July, affected growth noticeably by the end of September.

Soil management studies

In the trial in which comparisons are made on Laxton's Superb apple trees of the effects of clean cultivation, grass, and straw mulch treatments, started in 1951, the trees were mostly in their 'off' year. Cropping, however, is noticeably more regular on the cultivated plots than on those with grass or straw mulch, but the trees under cultivation showed poor foliage in 1957 and made little growth.

A study has been started, in collaboration with the Plant Analysis and Statistics Sections, to elucidate more fully the nutritional effects observed in this trial, taking into account the natural relationships between concentrations of nutrient elements within the tree. An intensive programme of leaf sampling has been undertaken to provide material for this study.

As another contribution towards the explanation of the results observed in this trial and in the trial in which the effects of different swards on Laxton's Fortune apple trees are compared, soil samples were taken during the winter and have been analysed by the N.A.A.S. Soil Chemist at Wye. In addition, the effects of clean cultivation, grass, and straw mulch on the soil in a trial concluded in 1956 have been described (p. 113) and the possible influence of these effects on fruit crops has been discussed in a bulletin (p. 155). An article on the competition for water by orchard swards (U6) and two general papers on orchard soil management (U7, U11) have been published.

Following the publication of a bulletin (U8), further observations have confirmed that oil sprays can give a useful control of couch grass around the base of fruit trees, and have emphasized the importance of application at the right stage, i.e., when the grass is 4-6 in. high.

The trial on the restoration of soil uniformity after grubbing a mature apple orchard is being continued in collaboration with the Statistics Section (p. 12). A paper is being prepared on the results of the first phase of this investigation.

Publications During the Year

U6 Goode, J. E. (1957). **Competing for water in the orchard.** *Grower*, **47**, 237-38.

U7 Greenham, D. W. P. (1957). **The environment of the fruit tree : managing fruit soils.** *Sci. Hort., 1955-56*, **12**, 25-31.

U8 White, G. C. (1957). **Weed control under fruit trees.** *Rep. E. Malling Res. Sta. for 1956*, 184-5.

U9 Goode, J. E. (1957). **Water needs of fruit crops.** *Sprinkler Irrigation Manual*, Wright Rain Ltd., Ringwood, Hants., 125-33.

U10 Roach, W. A., Vanstone, F. H., Philcox, H. J., Neve, R., Delap, Anne V., and Ford, Elsie M. (1957). **A method of growing apple trees by spraying their roots with nutrient solution.** *J. hort. Sci.*, **32**, 85-98.

U11 Greenham, D. W. P. (1957). **Grassing down and related practices.** *Essex Inst. of Agric. Tech. Pub.*, Soil and Water Problems in Fruit Growing, 20-4.

U12 Goode, J. E. (1957). **The irrigation of fruit crops.** *Essex Inst. of Agri. Tech. Pub.*, Soil and Water Problems in Fruit Growing, 25-31.

VI. PLANT ANALYSIS

By A. C. MASON

Studies on the mineral composition of fruit trees

While grubbing an orchard at East Malling, a tree more than 40 years old of Cox on an unknown stock was sampled in January to yield information on the distribution of elements in the roots, trunk and branches, and the total quantities of each element removed from the soil into the permanent structure of the tree.

The girth of the tree was $33\frac{3}{4}$ in. (85 cm.) and its freshweight was 0·74 lb. The roots were not carefully excavated so that most of the finer ones were left in the soil; this might account for another 25 lb. of fresh weight. The total dry matter amounted to 512 lb. and of this approximately 80 per cent was wood and 20 per cent bark, yet the bark contained 52 per cent of the total potassium and 33 per cent of the total nitrogen in the permanent structure of the tree.

The total nitrogen in the tree was 1,078 g., equivalent to 11·2 lb. of ammonium sulphate, and the total potassium was 657 g., equivalent to 3·2 lb. of potassium sulphate.

Assuming that 40 lb. of wood are removed as prunings annually and that an average crop of fruit is 100 lb., the amount of nitrogen and potassium removed from this tree annually in recent years would be about 67 g. and 50 g. respectively as prunings and 27 g. and 45 g., respectively as fruit, equivalent to an annual dressing per tree of 16 oz. of ammonium sulphate and $7\frac{1}{2}$ oz. of potassium sulphate. The gross amounts of these elements required by the tree during the growing season will be much greater on account of leaf production, the nutrient elements in which are, however, eventually returned to the soil. The above quantities are net amounts from which a simple calculation will show how much of applied fertilizers is lost, and the price which is paid to maintain adequate concentrations of these two elements in available forms in the soil.

In another experiment young trees of M.IX/IX and of M.IX/XVI have been grubbed at monthly intervals throughout the year. Detailed sampling of the trees has been carried out for chemical analysis of various parts and of the whole ; the data will be used for calculating the time of maximum demand for each element as influenced by rootstock, and the movements of nutrients according to season.

Leaf sampling technique

Between 15th and 20th July collections of leaf samples were made from 32 orchards of Cox/M.II apple trees growing in Kent, Essex, Suffolk, and Norfolk. The trees, mostly about 20 years old, were selected on the basis of their record of yield and fruit storage quality in recent years, high yields being contrasted with low, and much rotting with little (cf. p. 36). Three types of leaf sample were selected and fruit from the sampled trees has been received for chemical analysis.

The results of leaf analysis surveys reported from the U.S.A. do not agree with results obtained at East Malling on English varieties of apple. As Jonathan is a variety common to both countries it has been extensively sampled here when growing on two different types of soil and on a range of rootstocks. Thus a direct comparison will be made between the two countries for apples of the same scion variety and rootstock ; also the effect of rootstock on leaf analysis will be studied.

Sand and water cultures

In order to obtain as quickly as possible information on the effect of cultural conditions on the mineral composition of whole apple plants and their parts, sand and water cultures of 1-year rootstocks have been used. In a pilot experiment with duplicated M.VII rootstocks grown in water culture, a balanced nutrient solution was supplied at three widely spaced levels of total ionic concentration i.e. osmotic pressure values of 0·1, 0·5 and 2·4 atmospheres. Growth of the plants appeared to be unaffected, although the concentrations of the elements N, P, K, Ca, and Mg in the leaves, the stem and the roots were. All elements increased in concentration in the plant with increasing osmotic pressure of the nutrient solution, though not to the extent expected ; e.g. nitrogen in the leaves was increased from 2·57 per cent to 2·98 per cent by a 25-fold increase in total amount of nutrient in solution. The effect on concentrations of elements in the roots was greater. These interesting results will be tested more rigorously next year.

A sand culture experiment with 150 pots of M.II rootstocks was set up out of doors with the purpose of growing plants of widely different nutrient content. The concentration of each element in various parts of the plant will be compared with the concentration in the whole plant and with plant growth to determine which part serves as the best indicator of performance and nutrient uptake by

the whole plant. Growth data show that the plants were affected adversely by high concentrations of nitrogen, especially when supplied as ammonium sulphate.

Analytical methods

A method has been devised for estimating calcium, magnesium, manganese, and iron in plant ash solutions by the porous cup spark method. Limited experience with the method would suggest that the precision and accuracy for magnesium and manganese are good (±5 per cent) but that determinations of calcium and iron are less satisfactory.

The rapid arc method for direct analysis of plant ash has been thoroughly overhauled during the year and various improvements have been introduced. The elements K, Ca, Mg, Fe, Cu, and Al may be estimated with fair precision (about ±10 per cent) on 20 mg. of dried plant material. Estimation of phosphorus and manganese is less satisfactory and work is still in hand to improve the method for the latter element.

The colorimetric method for the determination of iron has been investigated to discover the reason for sporadic variations in determined values. The trouble has been traced to three causes which may operate together or separately (*a*) siliceous dust present on uncleaned leaves (*b*) the presence of vascular tissue which may give rise to a heterogeneous sample and (*c*) the presence in the leaf of compounds of iron which may resist attack by some commonly used reagents. Leaves should be thoroughly cleaned while still fresh, should have the petioles and midrib removed as completely as possible and the wet digestion should be done with an adequate proportion of sulphuric acid ; in this way accurate results may be obtained with a precision of ±2½ per cent. A full report is being prepared for publication.

Publication During the Year

VI Philcox, H. J. (1957). **A slide rule for calculating blackening curve separations.** *Spectrochimica Acta*, **10**, 119-27.

VII. PLANT PATHOLOGY

By R. V. HARRIS

BACTERIAL DISEASES

Bacterial Canker of cherry

Investigations into the systemic activity of streptomycin against the pathogen, *Pseudomonas mors-prunorum*, were continued. Penetration of the antibiotic into leaves was confirmed by infection experiments and by direct assay of leaves immersed for varying times in solutions of streptomycin. There is evidence of accumulation in the leaf and of slow translocation *via* the petiole into the axis of the shoot.

Resistant strains of *Pseudomonas mors-prunorum* were readily obtained by serial transfer through broth media containing progressively increasing amounts of streptomycin. By this means the maximum level of the antibiotic tolerated by the pathogen was raised from less than 1 to more than 4,000 parts per million.

In a field experiment, estimates of leaf-surface populations of the pathogen before and after spraying showed that colloidal copper was more efficient than streptomycin as a surface bactericide. Trees were sprayed with a mixture of these two materials as a possible means of combining good bactericidal properties with systemic protection. The mixture had about the same bactericidal activity as a colloidal copper spray, and did not give any better control of cankers.

In a field trial designed to test modified spray schedules, early autumn sprays of streptomycin or colloidal copper resulted in fewer cankers than later applications of strong Bordeaux mixture. Since colloidal copper is probably a less efficient bactericide than Bordeaux mixture this tends to confirm indications observed in previous years of the value of early autumn spraying

Preliminary work was started on bacteriophages (viruses infecting bacteria) for the typing and rapid identification of *Ps. mors-prunorum*. The soil beneath stone-fruit trees was found to be a good source of phages ; methods have been worked out to facilitate their isolation and several have been studied that differ in plaque morphology and in host range.

Cauliflower Disease of strawberry

The experiments on the survival of *Corynebacterium fascians* in field strawberries were continued. Plants into which a virulent strain of the bacterium was introduced at different times last year, have now been inoculated with eelworms in order to induce the cauliflower symptoms and so indicate the presence of the bacterium (see p. 31).

FUNGAL DISEASES

Apple and Pear Scab studies

Stock clones of *Venturia inaequalis* were maintained under paraffin oil at 5° C. Cox leaves were inoculated and the original clones re-isolated with little decline in pathogenicity.

Experiments in artificial culture and related trials on apple and pear trees under glass were continued in collaboration with Biochemistry Section on the activities of chemical analogues of caffeic acid as growth and sporulation inhibitors (see p. 17). O-coumaric acid and cinnamic acid proved to be the most toxic analogues tested. Trials under glass included further tests of cinnamic acid applied as a low-volume spray at 0·2 per cent on inoculated apple and pear shoots. The toxicity of this compound to both pathogens was confirmed and there was some indication that o-coumaric acid may be more active.

Verticillium Wilt Disease of hops and fruit

Studies in host-parasite relationships in hops

Previous investigations have indicated the probable significance of the endodermal layer of the root as a barrier to invasion of the vascular system of wilt-tolerant hops by *Verticillium albo-atrum*. Recent studies have suggested that the deposition of a waxy substance, suberin, in its cell walls may protect the wall from the action of the cellulose-destroying enzymes which are produced by the fungus, and which may facilitate its penetration of cell walls even though the enzymes are probably formed only in very small amounts in the host tissues.

If it can be confirmed that a high degree of tolerance is invariably associated with an increased capacity for endodermal suberization, it follows that *complete* exclusion of the fungus from the vascular

system is unlikely to be achieved in any variety, for near the root tip there will always be a small zone of immature endodermal cells which have not acquired the capacity to deposit suberin in their walls ; there is at present no evidence that, in the presence of a concentrated inoculum such as a piece of infected bine, the outer layers of the root of a tolerant variety could retard the ' progressive ' fungus sufficiently to allow the young endodermis to mature and to form suberin any more effectively than in a sensitive variety.

Pathogenicity tests

Experiments have been started on the host-parasite relationship in Strawberry Wilt (*V. dahliae*), with special reference to possible variations of wilt-tolerance in the host.

New wilt-tolerant hop varieties

Interim varieties.—Following the decision of the Station that the East Malling seedling varieties D/1 and D/3 should be released to the industry, wilt-free stocks of both were made available to the Propagation Committee of the Hops Marketing Board for allocation during the winter to specialist hop propagators able to propagate them for the A-plus Certificate of the Ministry of Agriculture, Fisheries and Food. These varieties will be named and fully described in the Annual Report for 1958. Continued observations of these varieties, and of the variety J/2, in commercial farm trials, have indicated that a generally satisfactory level of tolerance has been maintained.

Since the end of the year under report, it has been decided to release the variety J/2 on the same basis as D/1 and D/3, and also to issue basic healthy stocks of the wilt-tolerant Wye variety Bramling Cross (OT48) and of two wilt-tolerant varieties of male hop (Nos. 9 and B7).

Wye-East Malling breeding project

In the intensive tests for wilt-tolerance each of the eleven new seedling varieties tested this year proved to be as tolerant as OR55 (Keyworth's Mid-season). This phase of the project is nearing completion and preparations have now started for the commercial farm trials of the final selections.

Studies in the alternative-host and soil relationships of *Verticillium spp.*

Effect of various cover crops on survival.—The replicated field trial, mentioned in the previous report, is now well established ; this compares the survival of the fungus under bare fallow, bare fallow with organic amendment, annual weed cover and weed-free grass cover.

Two further trials which approximate more closely to hop-growing conditions were established ; one, on the Research Station, is designed to compare survival of *Verticillium* under weed-free grass cover with that under annual weeds ; and the second, in a grubbed commercial garden, is a direct study of the effect of weed-free grass cover.

Effect of tolerant hops on soil infectivity.—A field trial was established in a commercial hop garden where a severely wilted variety has been grubbed and replaced by Whitbread's Golding Variety (1147). The incidence of wilt in this tolerant variety will be compared each year with that in an annual planting of sensitive Fuggle N. This trial is designed to assess the effect of planting a tolerant variety on the quantity of *Verticillium* in the soil.

Direct observation of V. albo-atrum in soil.—Observations this year have confirmed those reported earlier : thus, following the death of infected plants vigorous sporulation occurs over the root surfaces. Mycelial growth into the surrounding soil rarely occurs and appears to be limited to growth from the root tissue across soil spaces. Under favourable conditions sparse sporulation may also occur on small soil particles adhering to root surfaces on which the fungus is sporing.

Effect of inoculum dose and type.—Plants of Fuggle N and the tolerant variety, OM26, were used to test the infectivity of bine fragments and spore suspensions over a limited range of concentrations. In Fuggle, wilt symptoms developed more rapidly with bine than with spore inoculations, rate of symptom appearance being related to concentration of inoculum. No symptoms developed in OM26 but on sampling *V. albo-atrum* was found to be present in more than half of the bines. Spores caused infection of both varieties, although to a lesser extent in the tolerant variety.

Conidial studies.—(*a*) *Survival* : Conidia remained viable in a test-soil for at least 14 days, but the maximum survival period has not been determined.

(*b*) *Germination and development* : Germination of conidia was inhibited in every soil tested. This inhibition was partly removed by heating soil for 1 hour at 60° C., and by addition of 1·0 per cent glucose solution, but not by amendment with 10 per cent activated carbon. The effects of roots and root extracts are under investigation.

Alternative hosts of V. albo-atrum.—Six isolates of *V. albo-atrum* from four weeds collected in wilted hop gardens (viz. groundsel, fat hen, annual nettle, and black nightshade) were tested in the pathogenicity testing tanks using Fuggle N as indicator. The isolates were compared with standard

'progressive' and 'fluctuating' strains from hops and were shown to be virulent strains of the 'progressive' type.

Collar Rot of apple (*Phytophthora cactorum*)

A wide range of rootstock varieties, including many of the Malling-Merton series, was tested by stem inoculation : the results will shortly be available. Preliminary experiments showed that this pathogen can attack the fine, fibrous roots of susceptible varieties and can severely impede their growth in infested soil without causing Collar Rot. Using apple fruits for isolating the fungus from the soil, marked seasonal activity of *P. cactorum* was demonstrated and this method may help in determining the most suitable time at which to apply soil fungicides.

Silver Leaf Disease

Progress was made in using young inoculated plum trees for testing chemotherapeutants against Silver Leaf (*Stereum purpureum*). Injection with 0·5 per cent or 0·25 per cent 8-hydroxyquinoline potassium sulphate caused only a temporary check to the disease. It appeared that the process of injection affected the growth of the fungus in the tree independently of the actual therapeutant used.

VIRUS DISEASES OF TREE-FRUITS

Apple

In experiments on the transmission of starcrack virus, the bark symptoms associated with the disease on Cox's Orange Pippin developed on indicator plants inoculated with budwood from nine orchards in south-east England. Differing degrees of severity suggest that there are several viruses or strains which can cause starcrack symptoms on the fruit.

A field trial was planted to investigate the effect of rubbery wood, mosaic, chat fruit, and starcrack viruses on the cropping of four varieties of dessert apples.

Pear

The quince stunt virus from Quince C was transmitted to apple seedlings and back to quince ; it produced no symptoms in apple. In the search for indicators for pear viruses, it was noted that *Amelanchier spp.* inoculated (by budding) with viruses that infect pear and apple have developed a red mottle on their leaves. As several different virus sources induced this reddening, further work is needed to show which latent virus is responsible.

A strain of Williams' Bon Chrétien, originally from Switzerland, formed strong graft unions with Quince A. This clone of Williams' is infected with vein yellow virus and attempts have been made to obtain virus-free scion-wood by heat treatment followed by propagation from the tips of young shoots.

Cherry

A clone of *Prunus serrulata* that has been propagated by layering shows promise as an indicator for necrotic ring spot virus. This clone has reacted differently from the Shiro-fugen variety, at present a standard indicator, and seems more sensitive to certain virus strains.

A virus in the west Midlands causing symptoms resembling those of the Little Cherry disease in British Colombia proved graft transmissible ; the orchard trees have carried small, bitter fruit for three successive years (see p. 122).

In the field trial planted in 1953 to compare the growth and yield of healthy and of virus-infected trees, the 1957 crop of Merton Bigarreau and Napoleon trees was reduced by infection with necrotic ring spot, necrotic line-pattern, and rugose mosaic viruses.

Plum

A field trial was planted to investigate the effect of prune dwarf, line-pattern, bark split, ring spot, and stunt viruses on the growth and cropping of four varieties.

Heat treatment applied in 1956 has apparently inactivated line-pattern virus from a late-ripening sport of Victoria. Four other varieties were treated in 1957, and the tips of shoots grown at a high temperature were propagated by soft-wood grafting.

In the development of a new indicator variety for line-pattern virus, twelve clones were propagated from myrobalan seedlings and inoculated in 1956. The three most sensitive clones are now

being tested with mild strains of the virus. Shiro plum and Early Laxton, the varieties previously used as indicators, have been shown capable of carrying line-pattern virus without expressing symptoms.

Virus-tested sources of scion varieties for the Mother Tree Scheme

The collection and testing of varieties for distribution in the Mother Tree Scheme has continued. As mentioned above, heat therapy is being applied to varieties of which no healthy material has been found, but this treatment has failed so far to yield healthy scion-wood of Roundel cherry.

Virus-tested material of seven varieties of plums is being propagated for distribution.

VIRUS DISEASES OF SOFT FRUITS

Strawberry

Work on the green petal virus was continued with particular emphasis on the way in which strawberry plants become infected in the field despite their apparent resistance to infection by the *Euscelis* vector responsible for spread in clover. The relationship of green petal virus to the other 'yellows' viruses known in Britain, *Rubus* stunt, hop nettlehead, and potato witches' broom, is also being investigated.

A disease, tentatively named 'Yellow Crinkle' was recorded in several varieties known to be tolerant of the usual crinkle virus complex. Severe symptoms have been seen on Huxley, Cambridge Favourite, Deutsch Evern, Mme. Lefebvre, and Cambridge Vigour. Preliminary results of transmission tests with yellow crinkle have suggested that it is distinct from, and not merely a severe form of, the familiar crinkle disease of Royal Sovereign and other 'sensitive' varieties. Yellow crinkle seems not to be transmissible by aphids.

Strawberry Nuclear Stocks

Fourteen varieties were propagated for 1957-8 issue to the Nuclear Stock Association. Varieties Redgauntlet, Sir Joseph Paxton, Jucunda and Cambridge Rival were issued for the first time.

An improved clone of Royal Sovereign (M.415) (see p. 8) was propagated to replace M.401 (re-cloned M.48) in the 1957-8 issue.

Loganberry and blackberry

Thirteen clones of vigorous Loganberries were indexed and all appear to be free from the virus isolated from 'degenerate' plants. The field performances of these clones are being compared by the Pomology Section (see p. 8).

Planting material was prepared for a field trial to assess the effect of the virus isolated from a 'degenerate' Loganberry. *Aphis idaei* and *Amphorophora rubi* have so far failed to transmit this virus but the tests are being continued.

Leafhoppers (*Macropsis* spp.) were tested as vectors of *Rubus* stunt virus ; the results of these tests should provide evidence on the identity of the virus causing *Rubus* Stunt in Britain with that in Holland where the vector is known to be *Macropsis fusculi*.

VIRUS DISEASES OF HOPS

Nettlehead Disease

Transmission of a virus from a nettlehead-infected hop to clover by means of dodder, and from clover to hop seedlings by means of leafhoppers, had indicated that a virus occurring naturally in clover may be the cause of Nettlehead disease. Further attempts were therefore made to infect clover from diseased hop using dodder and leafhoppers (*Euscelis* spp. and *Aphrodes bicinctus*), and also to infect hop from diseased clover ; the results of these tests are not yet available.

Attempts to transmit viruses from weeds, other than clover, collected in the vicinity of hop gardens in which nettlehead is spreading, have so far given negative results.

Further observations and reports of persistent nettlehead outbreaks associated with certain sites led to a start being made on a re-investigation of possible transmission through the soil.

A study was made of the heavy metal content of nettlehead infected hops and of the toxicity of nickel to hops. The results (see p. 129) show no causal relationship between nickel and nettlehead disease.

Mosaic Disease

Mites collected from *Prunus* spp. at the time of the spring migration of the Hop-Damson Aphid (*Phorodon humuli*) were tested as vectors of hop mosaic virus. No symptoms have yet developed on the test plants.

Split Leaf Blotch Disease

In the search for an indicator variety, several clones of Fuggle seedlings were propagated to be tested for sensitivity to split leaf blotch virus. The reaction of several new hop varieties to this virus is being studied in a replicated field trial.

FUNGICIDE INVESTIGATIONS

Small volume (concentrate) sprays

Apples

The primary object of current field experiments is to determine the importance of droplet-size in spraying against Apple Scab. Lime-sulphur was applied at three different ranges of droplet-size using a constant volume per acre and concentration ; conversely, with a constant droplet-size, volume and concentration were varied, so that the same quantity of lime-sulphur per acre was applied in each treatment. An experimental machine was devised and supplied by the National Institute of Agricultural Engineering for these experiments, which have already given interesting results despite unsuitable weather conditions.

Pears

Captan and lime-sulphur were compared, both as dilute and concentrate sprays, for scab control on dwarf-pyramid Comice and Williams'. Frost damage to the crop and the low level of infection on the foliage vitiated the trial except for information on spray damage ; in this respect captan was the more satisfactory material, especially on Comice, which was damaged by lime-sulphur.

Apple Mildew

A reliable method was developed for inducing uniform infection of unworked M.III rootstocks for use in fungicide investigations (see p. 33). A field experiment confirmed that early spring sprays have little effect in controlling mildew.

Greenhouse experiments on Apple Scab infection and control

Experiments made during the summer on unworked rootstocks in pots included studies of (*a*) methods of infection using ascospores and conidia, (*b*) the period of leaf wetness required for infection, and (*c*) the efficacy of lime-sulphur and mercury sprays when used as protectants or eradicants. Although mainly of an exploratory nature, the experiments have yielded sufficient information for the further development of rapid methods for testing the efficacy of fungicides in scab control.

Apple storage rots (*Gloeosporium* spp.)

The results of the second season's spray trial (1956) at Bassett's Farm, Horsmonden, showed, by contrast with those of 1955, that a captan spray in September gave improved control when preceded by a similar spray in August. This trial, carried out in collaboration with the Ditton Laboratory, has now been concluded and the results are being prepared for publication.

A new field trial was started in the autumn to test the efficacy of the systemic fungicide cinnamic acid in the control of these diseases when applied as a pre-harvest spray or used as a dip for the fruit after harvest.

Spore dispersal and meteorological conditions in relation to Apple Scab infection

Our co-operation continued with Dr. J. M. Hirst in his survey of spore-dispersal in relation to climatic conditions in different fruit-growing areas of the country. Records were taken by a Hirst spore-trap and self-recording meteorological instruments sited in the Station's plantations. This year the investigation became part of the country-wide N.A.A.S. Apple Scab Forecasting Investigations.

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VIII. ENTOMOLOGY

By A. M. MASSEE

Tree fruits

Woolly Aphid: testing apple seedlings

Twenty-one seedlings of Court Pendu Plat × Northern Spy and two of Court Pendu Plat × Crawley Beauty, found to be resistant last season, have been re-tested this year ; all exhibited the same degree of resistance as in the initial tests. Of 221 seedlings of Court Pendu Plat × Cox's Orange Pippin, and 58 of Cox's Orange Pippin × Irish Peach, all proved fully susceptible. Of 125 seedlings of Court Pendu Plat × Northern Spy, 50 per cent were found to be resistant following weekly inoculations. These will be tested again next year. In these investigations, the proportion of winged aphids was unusually high in August and September.

The importance of the production of Woolly Aphid resistant *scion* varieties will be fully apparent to all who have heeded the repeated statements that the Malling Merton rootstocks, while resistant to Woolly Aphid in themselves, do not confer resistance or immunity upon scions worked on them.

The nature of resistance is being studied in collaboration with the Pomology Section.

Apple Blossom Weevil

Inspection of selected plots has shown no evidence of reinfestation.

Ecological studies

The technique of manipulating relative densities of the Fruit Tree Red Spider Mite and *Typhlodromus* species on seedlings in the insectary has been extended. Comparison has been made between the response of *Typhlodromus tiliae* Oudms. and *T. findlandicus* (Oudms.) and known Fruit Tree Red Spider Mite densities in the presence and absence of abundant supplies of *Vasates fockeui* (Roiu.), an alternative prey of the predators.

Routine records of the fauna of the neglected orchard have continued ; most Mirid species were less plentiful than usual in 1957.

An experiment to assess the effect of predatory insects and mites on phytophagous mite populations has been started, the different predator levels being maintained by non-chemical methods. In the first year some success has been achieved in maintaining predator differentials and this is reflected in the Fruit Tree Red Spider Mite populations. The predators concerned are *Blepharidopterus angulatus* (Fall.), *Anthocoris nemorum* L. and *Typhlodromus tiliae* Oudms.

The study of the integrated action of insecticides and fungicides on the Fruit Tree Red Spider Mite and its predators was continued.

Owing to the abundance of *Blepharidopterus angulatus* (Fall.) in the previous year, populations of the Fruit Tree Red Spider Mite and leaf hoppers were so reduced that few established themselves this year. The predator itself was also scarce this year, possibly due to the scarcity of its prey at the end of the previous season. It would appear that the predator-prey interaction has completed its first cycle and has reached a level similar to that obtaining when the trial began in 1953.

To elucidate further the interaction of *B. angulatus* and its prey, a trial was started where the predators were destroyed on half the plot by the application of DDT to allow a differential population of prey and predator to develop in later years. It is proposed to study the development of the prey under differing predator pressure, and also the survival of the predator at different levels of prey by means of the capture-recapture technique for the adult stage (see p. 140) and a beating technique for the larval stages. A population of *B. angulatus* was studied on one of the control plots by the capture-recapture method to determine a workable plot size and the dispersal within the plot. An improved method of analysis of such data has been devised by the Statistics Section.

Studies were made on the fertility of *Psallus ambiguus* Fall. and *B. angulatus* under controlled and field insectary conditions.

At the Institute of Agriculture, Writtle, the Fruit Tree Red Spider Mite remained at a very low level in the Worcester experimental orchard, following one application of chlorbenside. The predator, *Anthocoris nemorum* L. has been abundant there throughout the season, but the Black-kneed capsid no longer occurs in the plantation.

Biology of aphids

Studies of species infesting apple, pear, currant and gooseberry are now almost complete, and the *Prunus* aphids are now being studied.

Concentrate sprays as a means of pest control

Preliminary experiments have been made using a motorized knapsack mistblower for experiments to assess pest control when insecticides are applied with concentrated lime-sulphur at less than 10 gallons per acre. This work is being carried out in collaboration with the Plant Protective Chemistry Section.

The value of spring washes for the control of apple pests

The results of a series of field trials during the period 1951-7 (carried out in collaboration with the Plant Protective Chemistry Section), combined with observations following applications of similar materials on commercial farms, indicate that satisfactory control of aphids, Apple Sucker and Winter Moth cannot always be achieved with a single pre-blossom application of DDT, BHC, a combination of DDT and BHC, or endrin. This is due to the different hatching periods of the pest species, the specificity shown by DDT and BHC, and the failure to obtain complete cover of the foliage by the current methods of spray application.

Codling Moth and other orchard Tortricids

Field trials to compare the values of ryania, diazinon, DDT, and lead arsenate for Codling Moth control have been carried out in collaboration with the Plant Protective Chemistry Section. The effects of these treatments on the Fruit Tree Red Spider Mite and leafhopper populations have been recorded.

The emergence of Codling Moths from overwintering sites in two types of cage has been recorded for comparison with data on emergence in the field, and the incidence of larval and pupal parasites has been studied.

The mercury-vapour light trap has again been used to record the flight period of Codling Moth and other orchard *Tortricoidea*. There has been a 90 per cent reduction in the number of *Adoxophyes orana* caught this season compared with the numbers trapped in 1953, 1954, and 1956. The factors responsible for this reduction are unknown, but it is possible that parasitic species may have achieved a much greater degree of control than hitherto.

Leafhoppers

The studies on the life-histories of *Erythroneura alneti*, *Typhlocyba froggatti*, and *T. rosae* have been continued, and observations have been made on the second-year effects of Codling Moth spray treatments on populations of these species.

In collaboration with the Plant Pathology Section work is in progress on the biology of some leafhopper species that are known or suspected vectors of Green Petal disease of strawberry. The pattern of feeding of these insects, in correlation with the leaf tissues affected, is under investigation in a variety of host plant species.

Studies of the life-history of the species of the genus *Macropsis* present on raspberry, loganberry and blackberry are still in progress. Excellent field control on cultivated blackberry has been obtained with malathion.

Bryobia Mite investigations

Studies of the life-histories of the *Bryobia* Mites associated with top and soft fruit, ivy, hawthorn, and grasses have been started. The problem is complex since several species or strains may be associated with cultivated fruits. The species found in commercial apple and pear plantations is extending its range and increasing in numbers each year. A survey is being made to discover the reason of this increase to pest proportions. It is now known that one strain of the *Bryobia* Mite persists every year in unsprayed orchards. The species found on gooseberry (*Bryobia ribis* Thom.) is distinct from that of apple, the former having only one generation a year.

Cold storage of plant material and insects

Studies on the cold storage of plants and insects, in collaboration with Ditton Laboratory have been continued. Methods have been established for storing leaves, shoots and plants to provide food for insects. Methods for storing eggs of predacious Mirids and winter eggs of Tetranychid Mites, on shoots of various fruits have been established ; in some cases these eggs can be hatched up to nine months after the normal hatching period, or by putting them into hibernation prematurely their hatching can be advanced by several months.

Insect rearing

Aulacorthum circumflexum (Buckton) was selected in 1955 as a standard food for insect predators, and methods for rearing it have been modified to a simple routine.

Studies of the laying and hatching of Mirid eggs are in progress. The work has made it possible to plan the production of Mirids for insecticide work. Two species have proved especially useful for bio-assay of insecticides.

Studies of the biology and rearing of Anthocorids, Coccinellids, and of the Tortricid, *Adoxophyes orana*, in relation to their use for insecticide studies have continued. Methods of rearing the ladybird, *Synharmonia conglobata* L. have been established in the laboratory.

Laboratory tests of insecticide residues have been carried out in field trials, to determine the persistence of insecticides and their influence on predators.

Deposition and persistence of insecticides

Combined chemical and biological studies of insecticide deposits on sprayed trees have continued, in collaboration with the Plant Protective Chemistry Section. Techniques for bio-assay, using larvae of Mirids and Tortricids, have been modified to make possible the analysis of spray deposits. Measurements of the persistence of a number of chemicals by chemical analysis and by bio-assay are in progress. Different ' apparent persistencies ' of the same deposit to different species (due possibly to different susceptibilities) have been shown.

Comparisons of emulsions and wettable powders of DDT indicate that deposits from wettable powders are more toxic to some species than equivalent deposits from emulsions.

Small fruits

Control of *Ribes* aphids

A further trial has confirmed that satisfactory control of aphids and of the Common Green Capsid on currants and gooseberries can be obtained by spraying immediately before the blossom period.

***Rubus* aphid: testing *Rubus* species**

Over two thousand separate tests were made in the insectary on raspberry seedlings of families showing resistance to *Amphorophora rubi* (Kalt.). Counts of aphid populations were made on seedlings planted out in the field in former years, and on selected varieties in a study of varietal difference in leaf preference and population fluctuation of the aphids. A large-scale survey of populations on Malling Landmark at many centres has been concluded. In the course of this investigation some apparently anomalous results have led to the study of the host range of different stocks of aphids; these have been shown to behave quite differently, and may be regarded as different strains. The work has been done in collaboration with the Pomology Section.

Black currant Gall Mite

The life-history of *Phytoptus ribis* Nal. is being investigated. A series of field trials have been carried out to evaluate the efficiency of endrin when both the concentration and time of application are varied. Analyses of fruit have been undertaken by the Plant Protective Chemistry Section to study the fate of spray residues.

Strawberry Seed Beetle and allied species

Further observations on the life history of the Strawberry Seed Beetle and other ground beetles injurious to strawberry have been made. In one experiment soil sampling to study population fluctuations in strawberry, in annual weed, and in permanent grass of all stages of the Strawberry Seed Beetle has started. Attempts to control fruit injury caused by this species by the application of an aldrin dust to the soil around the strawberry plants immediately before blossom were unsuccessful. Work has been carried out in collaboration with the Plant Protective Chemistry Section to determine whether aldrin or dieldrin in any combination of formulation, concentration, and timing will prove toxic to the beetles without leaving too much residue on the fruit.

Nematodes

Soil migratory nematodes

Work on this group of nematodes has continued, with special emphasis on the etiology of a case of ' slow decline ' of apple. Cherry replanting and Strawberry Root Rot problems are also receiving attention.

Some progress has been made in the development of techniques for the culture of *Pratylenchus penetrans* on apple seedlings grown in agar or sand. Approximately fifty-fold multiplications of small inocula have been secured after about 100 days. The technique is now being amplified and developed in an attempt to obtain numbers large enough for experimental inoculations of this and other species.

Attempts have been made to determine the cause of the increased vigour and root health of apple plants which has followed the destruction by moderate heat (60° C. for 30-40 min.) of the migratory nematode population of soil from a declining apple orchard. Substantial growth improvement has also been obtained on an apparently satisfactory apple orchard soil, containing few nematodes. This suggests that, in the cases studied, factors other than nematodes are also being affected by the heat treatment. Some of the more likely factors have been studied and it has been established that mycorrhizal invasion of the roots and an unidentified general soil fungistatic factor are greatly reduced. The effect of heat on plant macro-nutrients and heat-labile soil toxins has also been examined, but without finding anything to suggest that either factor contributes substantially to the observed improvement in growth.

Leaf and Bud Nematodes (*Aphelenchoides* spp.)

A field experiment on the infestation of strawberry plants with soil-borne *A. ritzema-bosi*, now in its fourth year, has confirmed earlier conclusions that artificial inocula became largely ineffective within 2-3 months. Evidence has also been secured of a slow but steady infestation due to natural causes, now involving about 10 per cent of the plants.

The inoculation phase of the collaborative field experiment with the Plant Pathology Section on the life of *Corynebacterium fascians* (Tilford) Dowson on strawberries, in the absence of *A. ritzema-bosi*, has been completed and the recording of results will begin next year.

Study of phytophagous and predacious mites

Phytoptid mite material has once again been received from various sources and has been determined. Various predacious species are being studied, and a paper concerning them has just been published.

PUBLICATIONS DURING THE YEAR

D301 MASSEE, A. M., and AUSTIN, M. D. (1956). **Investigations on the control of the Fruit Tree Red Spider Mite (*Metatetranychus ulmi* (Koch). II. Control by delayed-dormancy petroleum washes.** *J. hort. Sci.*, **31**, 239-43.

D302 ——— (1957). **Notes on some interesting insects observed in 1956.** *Rep. E. Malling Res. Sta. for 1956*, 131-4.

D303 GEORGALA, M. B. (1957). **A contribution to the biology of the Pear Sucker, *Psylla pyricola* Föer.** *Rep. E. Malling Res. Sta. for 1956*, 135-41.

D304 BRIGGS, J. B. (1957). **Some experiments on control of Ground Beetle damage to strawberry.** *Rep. E. Malling Res. Sta. for 1956*, 142-5.

D305 CHANT, D. C. (1957). **Predacious spiders and mites on fruit trees.** *Rep. E. Malling Res. Sta. for 1956*, 175-7.

D306 BRIGGS, J. B. (1957). **Some features of the biology of the Winter Moth (*Operophtera brumata* (L.) on top fruits.** *J. hort. Sci.*, **32**, 108-25.

D307 COLLYER, ELSIE (1957). **Two new species of the genus *Typhlodromus* Scheuten, 1857 (Acarina: Phytoseiidae).** *Ann. and Mag. nat. Hist.*, Ser. 12, **10**, 199-203.

D308 PITCHER, R. S. (1957). **The abrasion of the sternal spatula of the larva of *Dasyneura tetensi* (Rübs.) (Diptera: Cecidomyidae) during the post-feeding phase.** *Proc. R. ent. Soc. Lond.* (A), **32**, 83-9.

D309 PITCHER, R. S., and CROSSE, J. E. (1956). **An etiological association between nematodes (*Aphelenchoides* spp.) and *Corynebacterium fascians* in strawberry disease.** *Proc. 14th int. Congr. Zool.*, Copenhagen, 1953, 376-7.

IX. PLANT PROTECTIVE CHEMISTRY

By A. H. M. KIRBY

Insecticides

Analytical methods

Further work has been carried out on developing methods for determining microgram quantities of the following acaricides and insecticides : chlorfenson ; chlorbenside, and its oxidation products ; chlorobenzilate ; aldrin ; dieldrin ; endrin ; DDD ; DDE in the presence of DDT ; and *gamma*-BHC in the presence of large amounts of lime-sulphur. Preliminary work has been done on some newer acaricides, including 2,2,2-trichloro-1,1-bis(*p*-chlorophenyl)ethanol (FW293), and it is hoped to include fungicides in the coming year.

Studies on deposition and persistence

(*a*) Using the Aerograph pencil, the relationship between the magnitude of deposit achieved and the volume of spray applied has been shown to differ considerably from wettable powder to emulsion, a fact of importance in studies involving this type of spraying equipment. The effects of the concentration of active ingredient, and of the nature and concentration of surfactant present upon the deposit achieved, have been studied on apple foliage.

(*b*) In order to assess the part played by volatilization in losses from surfaces, studies of the rate of loss in still air from glass have been made in the laboratory, using *gamma*-BHC, DDT, DDE, DDD, chlorobenzilate, chlorfenson, and chlorbenside and its oxidation products. It is recognized that adsorption to leaf cuticle, as distinct from penetration into the leaf, may differ from that to glass.

(*c*) In the joint trials with the Entomology Section on the control of aphid, sucker, and caterpillar on apple by spring application of DDT and BHC, or of endrin, analyses confirmed that the initial deposits were proportional to the concentration of insecticide applied. Analyses and bio-assay made at intervals after the initial application, also confirmed that BHC had only short persistence, but that endrin had a similar life to DDT. These results were followed up by spraying pure samples of *gamma*-BHC, DDT, aldrin, dieldrin, endrin, and isodrin at the same concentration and in the same formulation on to apple foliage; the initial deposits and persistence of DDT, dieldrin, and endrin were similar, but those of *gamma*-BHC and aldrin were much less, isodrin being intermediate. Thus the more volatile insecticides may be lost to an important extent before they ever reach their target.

(*d*) Further trials were undertaken in collaboration with the Entomology Section to compare lead arsenate, DDT, ryania and diazinon for control of Codling Moth and other orchard insects and mites.

(*e*) Chemical analyses of DDT deposits on and in apple foliage, using cold solvent washing to indicate surface deposits and hot solvent extraction to indicate non-surface residues, with parallel bio-assays, have shown that the toxicity of such foliage to insects, such as mirids, that do not eat leaves falls off much more rapidly than the total DDT content. On the other hand, more mirids are killed by the same amount of DDT residue from a wettable powder than from an emulsion. These results accord with the view that DDT entering the leaf is lost as far as toxicity to this type of insect or as far as contact toxicity to leaf-eating insects is concerned.

(*f*) DDT is well known to be degraded by biological systems to the dehydrochlorinated product, DDE. The extent to which this is concerned with disappearance of DDT from foliage is being studied.

(*g*) Using the cold and hot solvent technique referred to above, followed by chromatographic separation, it is hoped to sort out the penetration and oxidation processes undergone by deposits of the acaricide, chlorbenside.

Harvest residues on soft fruit

Strawberries.—The results obtained in preceding years following spraying of strawberry plants at strawing-down with dieldrin to control ground beetles have been confirmed ; the minimum residue from post-blossom spraying is likely to be 0·5 to 1·0 p.p.m.

Black currants.—In view of the interest in the use of endrin for control of the gall mite causing Big Bud and Reversion on this host, work has been started to assess the magnitude of residues at harvest.

Fungicides

Glass-slide method

Further investigations have been carried out on the variation occurring in the glass-slide spore-germination technique in the presence and absence of toxicants, using *Venturia inaequalis* as test organism. Results so far indicate that the variation is greater between slides within the same moist

chamber than within circles on the same slide ; there is also variation between moist chambers within the same incubator.

Powdery mildews

In greenhouse tests of chemicals so far lime-sulphur and DNOPC have always proved superior to other materials for the control of Apple Mildew. Another approach would be to try to use DNOPC at lower concentrations by improving contact of the spray fluid with infected surfaces. A trial has, therefore, been started on small trees (Lane's Prince Albert) with standard and reduced rates of DNOPC, with and without an extra wetting-agent of a non-ionic type. This trial is primarily designed to assess the phytotoxic effects, if any, of such a combination ; it will take time for mildew to appear in any quantity even on the control trees. Preliminary greenhouse trials suggest that some surfactants may actually favour the incidence of powdery mildew.

Trials in the greenhouse have continued with M.III apple rootstocks to ascertain suitable rates of extra nitrogen and the duration for which it should be given before the rootstocks are used for inoculation. However, although rootstocks that had been cut-back and re-grown responded favourably in 1956 and again in 1957, the newly-grown stocks did not. By the eighth week, rootstocks not receiving extra nitrogen had smaller leaves, but even after nine weeks there was no influence on susceptibility to powdery mildew.

It was demonstrated that the most susceptible leaf on a shoot is the youngest, susceptibility falling off rapidly and exponentially with increasing age. Protective spraying may, therefore, be expected to require very frequent applications.

The stocks were growing well by the sixth week, and growth remained steady until the end of the experiment (tenth week), but the amount of infection achieved per unit area of leaf fell off rapidly from the sixth week onwards on all treatments. As the amount of inoculum applied could not be measured, it is not known whether this may have been partly or wholly responsible. Exceptionally hot weather may also have restricted the development of the fungus.

Cut-back stocks of MM.109 were also included in inoculation tests, but the new growth was poor and the comparatively small leaves were very resistant to mildew ; this stock would, therefore, be unsuitable as a replacement for M.III in these trials.

It is now fairly certain that, with greenhouse accommodation of the present type, investigations on apple will have to be confined to the summer. To speed up studies of chemicals and adjuvants, it will be necessary to use another species of powdery mildew on a suitable host which can be handled conveniently in shorter days, and work is now proceeding along these lines.

Phytotoxicity

Laboratory studies with copper sulphate on detached leaves have been extended by working with intact plants in the field. It seems that the behaviour of attached and detached leaves is fundamentally similar, such differences as appear being related to differences in environment which affect, for example, the rate at which the solutions applied will dry. Thus both types of leaf take up copper exponentially for a time and then linearly, but the exponential stage may be very short for attached leaves. An important cause of variability in the duration of the exponential stage has been found to be the time of day at which experiments are carried out, the earlier in the day that the copper sulphate is applied, the longer the duration of this stage, and *vice versa*.

Work in the field on the effect on penetration of copper of re-wetting treated leaves has shown that more and more of the copper in such deposits can be taken up.

A further step in these studies has now been taken by including a more complex system in the studies, namely Bordeaux mixture. Here there is a reserve of insoluble copper which may be expected to play a part, especially where the deposit is re-wetted.

Trials have continued on small apple trees on M.VII, on pears and on soft fruits. Reports of work with phenylmercuric chloride on Conference pear appears on p. 148, and with acaricides on plums and black currants on p. 152. The work with several phenylmercuric preparations on three pear varieties was continued, but severe wind damage in the spring and severe bird damage in the autumn have seriously prejudiced results both in this trial and in further trials with PMC on Conference. No damage was recorded on black currants sprayed with lime-sulphur, high or low volume, nor on Lane's Prince Albert apple where DNOPC is being applied with additional wetting-agents.

Publications During the Year

Q90 Kirby, A. H. M., and Tew, R. P. (1957). **Agricultural insecticides.** *Rep. Prog. appl. Chem.*, 1955, **40**, 653-65.

Q91 KIRBY, A. H. M., and FRICK, E. L. (1957). **Glass-slide spore-germination tests with some oxidation products of nabam.** *Rep. E. Malling Res. Sta. for 1956*, 146-51.

Q92 TEW, R. P., and GROVES, J. R. (1957). **Some observations on the effects of formulation on the persistence of DDT and its toxicity to certain orchard insects and mites.** *Rep. E. Malling Res. Sta. for 1956*, 152-60.

X. FRUIT STORAGE INVESTIGATIONS IN COLLABORATION WITH THE DITTON LABORATORY

By H. B. S. MONTGOMERY

Apple manurial trial

Storage comparisons were again made at 32° F. and 37° F. with the Cox's Orange Pippin from the manurial trial. For the fourth consecutive season the fruit grown with the sward treatment had the lowest rotting and breakdown, and applied nitrogen was associated with a higher incidence of losses from these causes. Applied potash tended to increase rots but decreased breakdown.

Determinations of cell size were made, as in 1955, on the cortical tissues of samples from a range of treatments, but the results were inconclusive. There was no correlation between fruit size and cell size as was found in 1955, and the respiration rates determined at Ditton showed no clear relationship with treatments. Chemical analyses were also made at Ditton.

Soil management trial

Most of the trees of Laxton's Superb in this trial were carrying a normal crop. Samples were stored at 32° F. and 37° F. and once again revealed the good keeping characteristics of fruit grown in grass sward. Losses from *Gloeosporium* rots were higher with clean cultivation or straw mulch at both temperatures. Breakdown in fruit from storage at 32° F. was low with apples from either the grass or the straw mulch treatment but was higher with those from clean cultivation. Parallel determinations of chemical composition and respiration rate were made at Ditton Laboratory.

Pruning

Cox's Orange Pippin trees on M.II, pruned by the established-spur system in the apple pruning trial, yielded apples that kept at 32° F. and at 37° F. with less wastage through *Gloeosporium* rots than apples from similar trees pruned by the renewal method or regulated. At 37° F., breakdown first appeared this year as a browning and cracking of the skin, and could not be related to treatment, but at 32° F., breakdown was more severe on fruit from established-spur pruned trees than from renewal pruned trees. There was a suggestion that the rotting was directly correlated with crop, and increased as the crop per tree increased.

Commercial samples

Samples of Cox's Orange Pippin were obtained from the same nine orchards in Kent, Sussex and Essex as in 1955-6, and stored at 32° F. and 37° F. This series of comparisons of orchards of good and bad storage history began with the 1953 crop, and six of the orchards, two in each of the three counties, have been included in all four years. The results for the 1956 crop did not agree well with those for the 1955 crop but, where continuous records were available, they agreed well with the results on the 1953 and 1954 crops. Chemical analyses were made on all these samples at Ditton Laboratory.

Survey of commercial fruit

Many samples of Cox's Orange Pippin were again collected at the Research Station from various parts of the country and stored in air at 37° F. and in gas (3 per cent oxygen and 5 per cent carbon dioxide) at 38°-39° F., and examined on 14th January and on 18th February respectively. The apples from gas store were in better condition than those from cold store, in spite of being one month longer in store, but losses from *Gloeosporium* rots were higher. A form of low temperature breakdown, visible without cutting the fruit, affected a number of the samples in cold store and traces of core-flush were rather more prevalent in the gas stored samples. More detailed information than in 1955 was obtained concerning the orchard histories of the samples and an attempt made to link storage behaviour with this information. For both cold and gas store, fruit from Norfolk had the fewest rots and was the least mature ; there were more rots on light soils, with spur pruning, and where low amounts of potassium had been applied ; fruit from young trees had less rotting than older trees, and the larger fruits had the more rots. There was no difference between fruit from grass and arable orchards.

As observed differences in fruit shape, colour and skin finish, as well as in storage quality, could not be linked with the treatments of particular orchards, scion wood was obtained from 24 selected individual trees and grafted onto M.IX rootstocks in the spring to see how far these differences may be maintained by vegetative propagation. A further set of trees for this purpose is being raised on virus-tested M.VII rootstocks by budding.

Leaf samples for chemical analysis were collected during July from marked trees in 32 of the orchards (cf. p. 20). The orchards were selected on the basis of cropping performance and the storage behaviour of fruit from them in these experiments during the past three years. Samples of the apples from these trees were also taken for analysis in the autumn when the fruit arrived at East Malling to go into store.

Other investigations

Samples of Cox's Orange Pippin have been collected at frequent intervals from blossom until picking ; these are being examined to find out if there is a relation between seed development and the cell division and cell expansion in the fruit cortex.

In the 1957 season the endosperm of these fruitlets began to become cellular about 40 days after pollination, while cortex cells were still dividing about 45 days after pollination. Cortex cell expansion occurred at the same time as cell division, beginning as soon as the fruitlets began to enlarge after pollination.

Fruitlets and fruit have been sent throughout the growing and storage season to the Biophysical Laboratory of Leeds University for the continued study of cell and cell-wall constituents.

Publication During the Year

T59 Marsh, R. W., Montgomery, H. B. S., and Edney, K. L., (1957). **Experiments on orchard spraying for the control of *Gloeosporium* storage rots of apples.** *Plant Pathology*, **6**, 39-41.

XI. MISCELLANEOUS PUBLICATIONS

T60 Montgomery, H. B. S. (1957). **Progress in research in fruit crops in 1956.** *Rep. E. Malling Res. Sta. for 1956*, 186-91.

T61 **Abstracts and Index to the Annual Research Reports 1913-1953.** (1957)

T62 **Subject Index of papers from East Malling Research Station in publications other than the Annual Reports between 1913 and 1953.** (1957)

Part III

RESEARCH REPORTS AND REVIEWS

GENERAL

AMOS MEMORIAL LECTURE*

VIRUSES AND VIRUS DISEASES

By F. C. BAWDEN, M.A., F.R.S.

It is, of course, a great compliment to be invited to give the Amos Memorial Lecture and I perhaps appreciate it all the more because I cannot lay claim to have contributed anything to the science or art of fruit and hop growing. My experience with these two kinds of crop is that of a mere consumer of end products and, if I felt I had to talk to you about them, my feeling of embarrassment would greatly outweigh my appreciation. To avoid this, and so that I shall not feel too much of an ignoramus among experts, I propose to interpret the invitation as an acknowledgement of the troubles and losses experienced from viruses by growers of fruit and hops and of your wish to have a summary of present knowledge about these elusive entities. I shall therefore try to give you a general account of the properties and behaviour of plant viruses, with only passing references to those that infect fruit crops or hops.

My justification for doing this, and I imagine the reason for my being here, is that, despite the great advances in knowledge about virus diseases of fruit and hops in recent years, there is much more known about some viruses that infect other crops, such as tomato, potato and bean. Indeed, the nature of any virus of importance to fruit or hop growing has yet to be determined. This implies no criticism of those who study the virus diseases of fruit and hops, but means only that these plants are very difficult experimental subjects and that they and their viruses are less amenable than others to study by laboratory techniques. In this connexion, it is worth stressing that the nature of most viruses, even of those that infect more amenable plants, is still undetermined. Our knowledge comes from work on a small minority, and of these the first virus to be recognized, tobacco mosaic, still continues to be the main provider of new information. There are very good reasons for this. It is one of the easiest viruses to transmit, it is remarkably stable when extracted from plants, it multiplies so extensively that it is readily obtained in large amounts, and it can be assayed with reasonable accuracy.

It would, of course, be dangerous to assume that what is true of one virus in one host is also true of another virus in a different host, but we must get information where we can. There are obviously considerable differences between a stable and an unstable virus, but there are enough features common to the behaviour of the many invisible pathogens we call viruses to suggest that they form a natural biological group. The distinction between viruses that infect fruit and those that infect other crops, which used to look so sharp, is also becoming increasingly diffuse, as more and more viruses are found to be transferable between such pairs of plants as peach and tobacco, cherry and cucumber, raspberry and tobacco, or strawberry and clover. I think, then, that although each virus will have its own unique properties, we may take it that those that trouble fruit growers will not differ fundamentally from those about whose constitution something is known.

I have already defined a virus as an invisible pathogen, which, less briefly but without jargon, means something too small to be seen by ordinary microscopes and that causes a disease in some organism or other. This tells us that viruses are smaller than fungi and bacteria or other usual causes of infectious diseases, but does not take us far towards understanding what they are. Nor does the fact that no virus has been cultivated on dead culture medium, for although this suggests a limited capacity for independent activities, there are also fungi and bacteria that have not yet been grown except in other living organisms. The prime question about viruses is : are they similar to pathogenic organisms, but simply smaller than others, or are they something fundamentally different ? This question is not solely academic, for although it needs answering to satisfy intellectual curiosity, it has

* The tenth Amos Memorial Lecture, delivered at Wye College on 14th November, 1957.

practical implications. If, as used to be assumed, viruses are ultramicroscopic organisms, then the control of virus diseases could reasonably be sought along traditional lines, but if they are not, then different methods will probably be needed from those that control fungal and bacterial diseases.

That the control of virus diseases does call for different methods is now obvious enough and our current knowledge of viruses gives ample explanation for this. All the viruses that have had their constitution determined fall into a biological category fundamentally different from even the smallest bacterium. It is not only that they are smaller than bacteria and that some have particles of such a uniform size that they can be obtained in crystalline forms, although this is a striking character, but more important is that they are chemically much simpler, are much more constant in constitution, and multiply in quite a different manner. Indeed, their closest relatives seem not to be bacteria, but the materials in the chromosomes and cytoplasm of normal cells that are responsible for inherited characters.

Like these normal cell materials, the virus particles have two components, protein and nucleic acid. The viruses are larger than most other nucleoproteins that have been studied and, although much too small to be seen by ordinary microscopes, they are readily resolved by electron microscopes. Each virus has a characteristic type of particle, but those common in crop plants fall into three main groups. First, there is a group with spherical, or near spherical, particles ; evidence is being accumulated that some of these are polyhedra and not spheres, but that need not concern us here. The other two are elongated, one group with seemingly rigid rods and the other more flexible and thread-like. The viruses that attack bacteria are more entertaining : some of these have distinct heads and tails, but despite their resemblance to miniature tadpoles, they also seem to be composed exclusively of protein and nucleic acid.

These bacterial viruses are worth some comment, not because the possibility has been raised of using them to control bacterial diseases of fruit trees, but because work with them has given much valuable information about virus multiplication. The tadpoles are not solid masses of uniform nucleoprotein, but the nucleic acid is carried inside the head, the outside of which, like the tail, consists only of protein. When the virus infects a bacterium, its protein remains outside and little, if anything, except the nucleic acid enters the host. This, though, is all that is necessary to set up the chain of events that within minutes leads to the production of more virus particles, complete with heads and tails.

Although the viruses that infect higher plants lack tails, there is growing evidence that they may behave in some ways like the bacterial viruses. There is good reason to think that the nucleic acid of some of the quasi-spherical viruses is carried internally, surrounded by a protein shell. And the rods of tobacco mosaic virus, which look so solid when covered with metal and photographed with the electron microscope, are probably hollow tubes, with the nucleic acid embedded between two layers of protein. With this virus, too, there is good evidence that infections, which lead to customary symptoms and to the formation of normal virus particles, can be caused by the nucleic acid alone. When separated from its protein trappings, however, the nucleic acid is unstable and soon loses its infectivity in conditions harmless to the intact virus. The separated fragments can be recombined to give rod-shaped particles closely resembling the original virus particles and, provided the nucleic acid did not become inactive before the recombination, the reassembled particles will be infective and again have the customary stability of the virus. Here surely is evidence in plenty of the fundamental differences between viruses and organisms, for no cell could be reassembled and survive after being disrupted in a comparable manner. You will remember that ' All the King's horses and all the King's men couldn't put Humpty Dumpty together again ', but all that is needed is exposure to acid or ammonium sulphate to remake particles of tobacco mosaic virus.

Knowledge of viruses, then, is quite incompatible with the idea of virus diseases being equivalent to bacterial or fungal diseases and the result of one organism preying on another. The relationship of a virus to its host is much more intimate ; a virus depends on its host, not simply for a source of food, but for the manufacture of its whole substance. It becomes a part of the cell and its multiplication becomes part of the nucleoprotein production of the cell. If an analogy is to be sought, then we should perhaps go again to genetics rather than to bacteriology, and regard infection by a virus as somewhat comparable to the gaining of new characters when one variety is crossed with another. In normal cells, protein formation seems to be correlated with and determined by the nucleic acids, and virus infection implants a new nucleic acid which permanently influences a cell's operations.

No novel components have yet been identified in any plant virus : the amino-acids making up the protein part, and the nucleotides in the nucleic acid, seem to be identical with those in other, non-infectious nucleoproteins. Different viruses have characteristically different proportions of nucleic acid to protein and their nucleic acids also have characteristically different ratios of the four individual purines and pyrimidines. The nucleic acids from the different strains of tobacco mosaic virus yet examined have resembled one another closely, but the proteins may differ considerably, to the extent

that an amino-acid may occur in one strain but not in another. As the nucleic acid alone gives an infection of the same type as that of the strain from which it came, and combining the nucleic acid from one strain with protein from another does not alter its behaviour, the nucleic acids of different strains must obviously differ. The differences probably lie in structural configurations rather than in amounts of components, with the specific characters of each strain and the structure of the protein formed being determined by the precise way in which the nucleotides are arranged.

The mechanisms responsible for the type of symptoms shown are still unknown, but it is the proteins of bacterial viruses that dissolve the host cell walls, and so with the plant viruses the proteins may be responsible for aiding the virus particles from cell to cell and have other activities that interfere with the normal functioning of the host plant. It is clear that symptoms do not result simply from the amount of material that is diverted into the formation of virus nucleic acid and protein, because the severity of symptoms caused by different viruses or virus strains is not correlated with the concentrations they attain in infected leaves. Some strains of tobacco mosaic virus that cause relatively trivial symptoms in tobacco reach amounts more than 1,000 times as great as other viruses that cause crippling diseases. Indeed, it seems remarkable that plants can tolerate having half their total protein in the form of these strains of tobacco mosaic virus.

It is, of course, because they cause symptoms that viruses are important, and particularly because they usually have permanent effects. Not all symptoms are necessarily bad things and horticulturists have not been slow to make use of some, such as ' broken ' tulips and variegated *Abutilon*. Long before pathologists appreciated that the best analogy for a virus disease was the change of one variety into another, horticulturists were selling such virus-infected plants as new varieties, confident that they would continue to produce the prescribed effect, the attractively striped tulip blooms or the colourful *Abutilon* leaves. Many other plants also have their leaves and flowers altered strikingly by viruses, but there are few in which the changes are welcome, for they are accompanied by slower growth, a decreased yield and, with fruit, often a decrease in quality as well as quantity. Some plants are killed by some viruses, but more often infection results in a chronic debilitating disease. Symptoms may appear on any part of a plant, though the most common are mottles, yellowing or other discoloration, or deformity of the leaves. Strawberry Yellow-edge and Crinkle, Apple Mosaic, Cherry Ring-spot and Leaf Roll, and Line Pattern of plum are names that indicate the hallmarks of some diseases of fruit crops. Effects on flowers are some of the most helpful in diagnosis, for whereas the leaf symptoms of virus diseases are often confusingly like those caused by mineral deficiencies, only viruses seem to affect the colour and form of flowers. Variegated instead of uniformly coloured flowers we have already mentioned, and another feature equally specific to virus infection is phyllody, the changing of petals to leaf-like organs, as in Strawberry Green Petal. Fruit may be small, as in Chat Fruit of apples or Little Cherry disease ; malformed, as in Stony Pit of pears ; or disfigured, as in Rough Skin and Star Crack in apple. And stems may be disfigured, as in Bark Split of plum, or lose their normal rigidity, as in Rubbery Wood of apple.

Symptoms are such variable things that there is little point in describing them in detail. Most viruses exist in a great range of strains each of which produces a characteristic effect in some plant or other, and one strain may cause very different symptoms in different kinds of plant. Even with one strain of a virus in one variety of plant, symptoms vary greatly, depending on the conditions in which the plant is growing, its age and condition when infected, and the length of time it has been infected. It is common for plants to support a high virus population and to show severe symptoms when they first become systemically invaded, a phenomenon in trees sometimes called a ' shock ' reaction, and then to show less severe symptoms as time goes on. Plants sometimes seem to recover completely from infection, but despite the disappearance of symptoms, they still contain virus, although usually much less than when showing symptoms. Like infected plants that never show any symptoms, these recovered plants provide sources of virus for other plants, sources all the more dangerous because they seem above suspicion.

The inconstancy and variability of symptoms greatly complicate diagnosis, and it is rare rather than usual to be able to identify with certainty a virus from symptoms only. For reliable identification either serological or plant-protection tests are needed ; the first are quicker, cheaper and more reliable, but they are limited to those viruses against which antisera can be prepared ; the second are more generally applicable and rely on the fact that plants infected with one strain of a virus are usually refractory to infection by a second strain although still susceptible to infection by an unrelated virus. Indeed, two unrelated viruses often give a more severe disease, and sometimes one of quite a different type from that given by either virus alone. From the examples of this phenomenon that have been studied, it seems that infection with one virus usually greatly increases the extent to which the other multiplies. Sometimes, too, plants that have ' recovered ' from a virus disease will show typical ' shock ' symptoms again when infected with a second virus, and symptomless carriers of a virus may show a more severe disease when they get infected with a second virus than they would if

infected with the second one alone. It is due to this ability of plants to continue to become infected with additional viruses unrelated to those they already contain, and to such interactions between these viruses, that the cropping power of clonal varieties continually decreases as they grow older.

It is the permanence of virus infection that makes viruses particularly important in tree or in other crops that are expected when planted to continue cropping for many years. Viruses are prevalent in all kinds of crops, but in annuals the most infection in one year can do is to damage that year's crop. Infection of perennial plants in any one year, however, means not only loss of crop in that year, but a lowered yield thereafter. It is not simply loss of income ; it is a loss of capital too. Fruit growers therefore need to take special care to avoid virus diseases, particularly as they use all the methods of propagation that a virus worker would design to perpetuate and spread his pet viruses.

It is characteristic of viruses in crops they harm to spread through almost the whole of the vegetative parts and, as already stressed, to stay permanently in invaded cells. It is, though, exceptional for viruses to enter the pollen or egg cells, and sexually produced seeds are usually virus free. Reproduction by seed provides a cleansing process whereby species free themselves from viruses. What prevents most viruses from being seed-transmitted is unknown, but the speed at which plants when propagated vegetatively can lose their vigour because of virus diseases makes it clear that some such cleansing process was necessary if plants were to survive. You will all know of good and useful varieties that went out of cultivation because they had ' degenerated ' or ' become senile ', old phrases we now know usually meant had become too affected by viruses to be worth growing any longer. Vegetative propagation is the standard practice in fruit and hop growing and I am not going to suggest it should be abandoned, for I know that the clonal variety is essential to ensure high quality and uniform behaviour. But what I am going to say, and say forcibly, is that to rely on clonal varieties, without appreciating and allowing for virus diseases, is to ask for trouble. Each time infected plants are propagated by tubers, bulbs, runners, cuttings or the like, all the progeny will come virus-infected ; and each time a graft is made, if either scion or stock is virus-infected, then as soon as there is an organic union between the two, the virus will pass from one to the other.

In using clonal varieties, therefore, it is essential to ensure that only healthy plants are used as sources of propagating material, and it is to this end that health certification schemes have been introduced for many crops. Fortunately, it should be much easier in the future than in the past to ensure starting well. Existing varieties that are now virus-free can be kept that way, but there are also methods known for freeing infected plants from at least some of their viruses. So far the only method that has been used extensively is heat therapy. With a few viruses and plants, a short exposure to a high temperature, such as provided by a dip in hot water, is enough, but of more general use is the growing of plants for some days or weeks continuously at temperatures around 37° C. How it works is still obscure, but it seems that virus multiplication in a cell is normally a continuing process and not something that happens once and for all ; the concentration at any one time, like that of the normal nucleoproteins, reflects the physiological state of the cells and is a balance between the two opposing processes of synthesis and break-down. High temperatures encourage protein break-down, and viruses that fail to maintain themselves in plants kept continuously at 37° may disappear because their protein is disrupted and their nucleic acid then exposed to cell components that inactivate it, or the high temperature may directly affect the nucleic acid. The explanation, however, is less important than the fact that the method works and that it has produced virus-free lines of some clonal varieties, the whole stocks of which were previously infected.

Not all virus diseases are amenable to simple heat therapy, but there are other promising possibilities for cures. One of these was implied by the word ' almost ' when I said earlier that viruses invade almost the whole of the vegetative parts of plants, and this remark now needs to be made more precise. The symptoms of virus diseases usually show most vividly on young, rapidly growing tissues, but the youngest cells of all seem insusceptible, and the undifferentiated ones that compose the growing points of stems are often, even if not always, virus-free. Again, as with pollen mother cells and egg cells, we do not know the reason for most viruses failing to invade such cells, but nucleic acid synthesis is already intense in dividing cells and a simple explanation could be that they are so engaged already with one type of nucleic acid formation that they cannot be deviated into another. Whatever the explanation, the fact can be made use of to produce clean lines from plants infected with some viruses. By excising the apical meristems, and culturing them on nutrient media until they put out roots and leaves, and then transplanting into soil, virus-free lines of such previously infected plants as King Edward VII potatoes and various chrysanthemum varieties have been obtained.

Again this method on its own is unlikely to be universally applicable, for as some viruses are seed-transmitted so some are likely to invade apical meristems, but used in combination with other treatments it may prove to have wide applications. For example, viruses that are not wholly inactivated in plants at 37° often fail to move into new tissues formed at this temperature as readily as they do at lower temperatures, and apical meristems that will grow into virus-free plants may be obtainable from

plants previously kept hot even though not from those grown under usual conditions. Also, some substances, particularly analogues of purines and pyrimidines, decrease the rate of virus multiplication when sprayed onto infected plants or given through the roots, and although we are yet far from any chemotherapy for virus diseases, such treatments may well help to obtain virus-free, viable meristems. So, too, may treating plants with hormones such as gibberellic acid, which cause stems to elongate rapidly.

These are all exciting possibilities that still await full-scale testing, but that some will work there is no doubt. We are now reaching the stage, I think, when no variety need ever be discarded simply because it has become virus-infected and when the crop certification schemes will be able to operate more certainly and reliably than before, because they will be based on clones whose appearance and behaviour when virus-free is fully known. In the past there is little doubt that virus-infected lines have been unwittingly distributed from many nurseries. Indeed, it is impossible with such crops as top fruit to know how much the current prevalence of some virus diseases reflects spread in standing orchards and how much the planting of already infected trees. Cleaning-up the nurseries will not only benefit the grower of fruit, but also the nurseryman. Work at East Malling has clearly shown that graft incompatibility often simply reflects the fact that either scion or stock is virus-infected, and that the use of virus-free scions and stocks increases both the growth rate of young trees and the uniformity of the stand. Here, then, is a method whereby the nurseryman will be able to supply his customer with a better product and also more accurately forecast his own production.

The planting of virus-free material is the first essential step towards the control of virus diseases and will itself prolong the useful life of crops, but will not guarantee perpetual health. It is difficult to speak in general terms about how much can be done to keep healthy crops free from virus diseases, because different viruses spread in such different ways. Even the same virus, and even when being transmitted by the same method, may spread at very different rates in two kinds of plant, for one kind may be more easily infected, maintain a higher virus content or differ in some other way, such as being more favoured by an insect vector, that makes it more liable to contract infection than the other. Most of the viruses whose spread has been studied in detail have been found to be transmitted by insects or some other arthropod. Spread is not a simple mechanical affair, done by any insect that chances to feed first on an infected plant and then on a healthy one, but each virus is transmitted specifically by one or by a limited group of similar insects. In the United Kingdom aphids have been found to be vectors of more viruses than have all other arthropods put together, but increasingly vectors are being identified in other groups and they are now known in such widely differing ones as leaf-hoppers, thrips, beetles and mites.

The great differences in the incidence of many virus diseases in the United Kingdom from year to year mainly reflect the way the weather affects the numbers and activity of the insect vectors. The unusual prevalence of virus diseases of sugar beet and potatoes in 1957, for example, resulted mainly from the unusually heavy and early aphid infestations, in their turn a consequence of the unusually mild and short winter, which also probably allowed more than usual numbers of infected plants to survive and provide sources of infection. The rate at which some of these viruses can spread is truly formidable. Between April and September this year, more than 90 per cent of all the sugar beet in this country became infected with the yellows virus, and many individual crops were all infected by August. Such a rate of spread would be ruinous in any perennial crop ; indeed, with viruses that seriously damage trees, a rate of spread that only doubles the incidence annually can have catastrophic effects, as has been amply demonstrated by such diseases as Peach Yellows, Elm Phloem Necrosis and Citrus Decline in the United States of America, and by Cocoa Swollen Shoot in West Africa. We are fortunate that so far nothing of this kind has afflicted our tree crops, although there are diseases of cherry that seem to be reaching serious levels. It is for these virus diseases of trees that, more than anything else, some chemotherapeutic treatment is needed. With short-lived crops treatment of individual plants is rarely likely to be economic, and to get a treatment that can be easily applied and will get rid of viruses without temporarily damaging the host seems at the moment only a pipe dream. But for an elm, or for a fruit tree in full bearing, a considerable expense would be justified and, even if the treatment was temporarily damaging, this would be a small price to pay compared with losing the tree. At the moment killing infected trees is the only advice that can be given, in the hope that destroying sources of virus will prevent spread to still healthy neighbours.

When more is known about the vectors of tree viruses it may become possible to check their spread by the use of insecticides. These are already being applied with some success against aphid-transmitted viruses in crops as varied as strawberry, potato and sugar beet. As there are substances that are effective against all the kinds of arthropods that are known to spread viruses, it is worth devoting a few minutes to considering the reasons why these substances are not the complete answer to virus diseases. First, let us be clear that there is a great difference between controlling insects as pests and in controlling them as transmitters of virus diseases. The first requires only that numbers

are brought below those that do direct damage. With aphids this means in effect preventing the enormous populations of wingless types that can develop within a crop. However, the spread of a virus requires that an insect should move and, during its moving, feed first on an infected plant and then on a healthy one. Most of the wingless ones never do this, and the spread of viruses mainly results from the activity of the winged ones, a minority of the population.

The winged aphids can increase the incidence of infected plants in a crop in two ways ; one by bringing in virus which they have acquired by feeding on plants before they come into the crop, and the other by spreading virus from already infected plants in the crop to their healthy neighbours. With aphid-transmitted viruses in Britain, incidence usually increases more by the second than the first method, but this is not always so and sometimes so many infective aphids come into crops of sugar beet and lettuce that a large proportion of the plants become infected before there has been any spread from plant to plant within the crop. The use of insecticides so far has mainly been of benefit in preventing spread within a sprayed crop and less in protecting against infection by aphids arriving already infective. The reason for this is simply that current insecticides do not kill such incoming aphids quickly enough to prevent them from infecting at least the first plants on which they chance to feed. Their success in preventing spread within a crop is also not complete and it varies greatly with different viruses, depending on the way in which they are transmitted. Here is no place to describe all the different ways, and the two extremes must serve to illustrate the extent to which behaviour of individual viruses affects the extent to which their spread is interfered with by insecticides.

At the one extreme are viruses whose aphid vectors can become infective by feeding on infected plants for less than a minute, and they can also transmit to another plant within the next few minutes. The vectors of such viruses usually cease to be infective soon after leaving an infected plant, often within minutes if they feed on a healthy plant and within hours if they do not feed. The spread of such viruses is largely a local event and insecticides will have little effect on their spread, whether into a crop or within the crop. At the other extreme are viruses whose vectors do not become infective for some time after they have first fed on an infected plant ; with some the delay is hours and with others days, but once they become infective they usually remain so for a long time, some for their whole lives. The spread of these viruses within a crop can be almost wholly prevented by spraying the crop with a suitable persistent insecticide ; their entry into a crop will not be prevented but will be lessened, for although the incoming infective insects may infect the first plants on which they feed, they are likely to be killed before they can infect as many as they might in unsprayed crops.

However, there are also many other factors that determine whether insecticides are likely to be of practical value, and not least the life history of the insect vector. Viruses that are spread by the Strawberry Aphid, for example, should be easier to control than those spread by the Peach-Potato Aphid, for the first has only one host plant and one migratory period a year, whereas the other has a multitude of host plants and produces winged forms at different times. Spraying healthy stocks of strawberry plants, though, will not be enough to keep them healthy, for it will not prevent viruses being brought into them by aphids migrating from diseased stocks. Spraying the diseased stocks before the migration would, in fact, probably be a better safeguard for healthy stocks than spraying the healthy stocks themselves, but unfortunately this is not within the compass of those growing the good stocks. Spraying the healthy stocks, then, must be accompanied by inspection and roguing to get rid of infections introduced from elsewhere ; and this would probably still be necessary even if all strawberry crops in the country were sprayed, for this would not prevent the occurrence of such diseases as Green Petal, which are probably introduced from such plants as clovers or weeds.

The use of insecticides to control virus diseases is still in its infancy and there is no doubt that it will be greatly developed. However, let us not be too optimistic, for even if spraying provides a control for many of the diseases, it will not be a universal preventive. Not so long ago we might have thought so, but now we know there are many soil-borne viruses, including some of fruit, for example, the cause of Leaf Curl of raspberry in Scotland. How these viruses survive in the soil and how they spread from plant to plant are questions that stand unanswered, posing problems as fascinating as any yet solved.

PRACTICAL ASPECTS OF FIELD EXPERIMENTATION WITH FRUIT

By T. N. HOBLYN

During the past thirty years much has been written about statistical methods for the design and interpretation of field trials and many different devices appropriate to various crops and kinds of experiment have been evolved and put to good use. The main objects of such designs are that the comparisons in the experiment should be sound and the conclusions able to stand up to a critical examination.

In the course of a long experience in designing such experiments with fruit plants, the writer has had it forcibly brought home to him that there are many points in planning that, while they are not strictly statistical, may make or mar the experiment. These include the wise selection of treatments, the provision of adequate plant material and the best use of the land available. These considerations involve no mathematical concepts and, indeed, are generally based on common sense ; but, nevertheless, they have not always been appreciated by those who are planning new investigations and are, therefore, perhaps worth summarizing.

Fruit experiments, whether in the field, the laboratory or the greenhouse, cover a very wide range, both in their nature and in the kind of fruit under trial. Thus, in the field, a comparison of methods of rooting cuttings may occupy a piece of ground 2 to 3 square yards in area, while a cultural experiment on sweet cherries may require several acres. In England, fruit crops range from strawberries to apple trees and may last anything from a few months to fifty or more years. There can be no hard and fast rules that cover such a diversity of investigations and, in general, each must be planned on its own merits.

Common principles

In the preliminary stages of planning a new enquiry, there are two main points to be observed.

First, the research worker should familiarize himself with everything concerning the subject that is already known. Hours of study in the library or examining the records of investigations of a similar nature that may have never reached publication, are seldom wasted and may save fruitless repetition of work.

Secondly, having cleared the ground, the investigator should ensure that the new trial is so designed as to be *capable* of giving a definite answer to certain clearly defined questions. It is sheer waste of time to embark on a trial that can only give a vague indication of what the answer is. Here, the statistician can probably help with an estimate of the number of replications likely to be needed and, if it looks as though there would not be room for enough, then the trial should be simplified by asking less questions. Vague ' variety ', ' pruning ' or ' manurial ' trials including many treatments insufficiently replicated, and in which there is no definite, carefully thought-out reason for the inclusion of each, may be responsible for much wasted land and labour.

Pilot trials

It is the purpose of this paper to describe some of the important points in planning full scale field experiments. Nevertheless, in the course of an investigation there is often a good case for the small scale, short-term pilot trial, where the number of treatments or varieties is large, because there is insufficient knowledge on which to plan a proper experiment. Such trials may be necessary to ' give a lead ', but the treatments or varieties that they include should be clearly different and the intention should be to eliminate the useless ones. Thus, pilot trials may be necessary to show whether any of a series of new spray materials that are promising in the laboratories are effective or are phytotoxic under field conditions. A series of new grass mixtures may be suggested—will they stand up to regular mowing, spraying, trampling, etc., and still form a good sward in a fruit plantation ? New herbicides may be satisfactory in the open, but can they be used among strawberries or black currants without seriously damaging the fruit plants ? Compatibility with standard scion varieties is an essential quality of a new rootstock for plums. A new series all root well in the nursery—are they all compatible with important varieties of plums ? Any that are not should be eliminated. There are many other examples, but one unalterable principle—the trial must be designed to give a black or white answer.

Full scale field investigations

Broadly, there are two main kinds of field investigation, apart from the intensive kind, which may be very like a laboratory study except that it is done in the open field. These are (*a*) Trials of Assessment, and (*b*) Directive Experiments. Both cover many different kinds of enquiry, but there is a fairly clear difference between them. Trials of assessment seek to compare the relative merits of such things as scion varieties, rootstocks, or even means of crop protection, where it is merely a matter of comparing different kinds of spray, or the same spray material at different times or rates of application. Usually, but not quite always, only one ' factor ' is involved, but the number of representatives within that single factor (e.g. rootstock) is often quite large. Directive experiments, in contrast, are designed to further knowledge of horticultural principles and generally include several factors. Primarily they may be concerned with such practices as pruning, manuring and spraying, but they are nearly always more complex than a straight trial of assessment. For example, a pruning experiment on apples will usually be carried out on more than one variety, while a cultural trial on cherries may have to include contrasting scion varieties, rootstocks and manuring, as well as differences in cultivation. Again, an experiment that aims at a better knowledge of the control of a particular disease is likely to cover spray material, time, method and strength of application, and may even be done on more than one variety—five factors.

Trials of assessment

Trials of this kind must usually be carried out in several stages, starting sometimes with the plant breeder himself. For example, in the breeding of late-blossoming apple varieties, it has been found that time of blossoming is correlated with time of leafing out. This fact is now used to eliminate many new seedlings at a very early stage, indeed long before they are old enough to flower. Similarly, the anatomy of a small piece of root may facilitate the preliminary sorting out of a range of seedling rootstocks.

In the past some variety trials planned as long-term investigations included far too many varieties, many of which were of no interest after a year or so and merely occupied valuable experimental land, while spoiling the comparison of the more promising ones. Here evidently a stage in the search had been missed.

The National Fruit Trials, in England, are a good example of this kind of study, receiving many new varieties for trial, often of unknown merit, except to their breeders. Evidently the first stage here is the quick pilot trial designed to obtain fruit of those varieties as soon as possible, and to find out their seasons of blossoming and ripening, obvious susceptibility to disease, etc. Trees may be close planted, grown on dwarfing or semi-dwarfing rootstocks, and pruned for early fruiting ; while replication need only be sufficient to ensure that one variety or another is not unduly favoured. In such a trial many sorts can be eliminated quickly. Only the best of the remainder should be selected for further long-term assessment of such qualities as size of tree and cropping under normal commercial conditions in comparison with an established variety of similar kind and season. This stage in the assessment trials will generally still be a simple one, though the number of varieties may yet be considerable, i.e. up to twelve or more, and it may be desirable to include a second factor, such as two contrasting pruning methods or rootstocks. However, the trial must be capable of withstanding a critical comparison of the cropping capabilities and other important characters of the new varieties with others of their class. For this, generous replication may be essential, while the multiplication of such trials under different soils and climates may also be most desirable. If the new variety is to be of value in commerce the production of sufficient fruit for market or processing tests may be very important—another reason for generous replication.

Directive experiments

In contrast to the above, directive experiments usually contain more than one factor and the answer may be in the form of what is known as an ' interaction '. Thus, it may be that ' regulated ' pruning is excellent for a ' tip-bearing ' variety, whereas the ' established-spur ' method is the only one for a variety that forms most of its blossoms on short spurs. Again, under shade, cacao may not respond at all to nitrogen applied to the soil, yet, in the open, annual applications may be essential. It is important, in planning, to try to forecast the form in which the answer is expected so that such interactions as the above may be particularly ' nominated ' in the experimental design.

Usually, though by no means always, the experiment is concerned with one or two major factors, the others being subsidiary. But, whatever factor is being considered, the levels within it should be few and clearly defined, while the subsidiary varieties, rootstocks or cultural treatments should be selected to represent a class, rather than because they themselves happen to be commercially important.

An experiment primarily designed to examine the effect of time of application of nitrogen to

strawberries is a good example of this kind. The main purpose of the trial might demand three treatments :

(*a*) All nitrogen applied immediately after cropping.
(*b*) Nitrogen applied half after cropping and half at the normal time in the following winter.
(*c*) All nitrogen applied in winter only.

But evidently other factors must be involved, e.g. variety, form in which nitrogen is applied and rate of application.

For variety, season is obviously important, so an early and a late-maturing variety are chosen. The forms in which the nitrogen is applied may be a quick one as compared with another that is available over a long period. For amount, the normal rate of application might be tried against a much heavier one. In each instance the differences should be clear cut and the actual chosen treatments not necessarily commercial.

Thus is arrived at what is now well known as a $3 \times 2 \times 2 \times 2$ factorial experiment, in which the interactions of time of application with variety, kind or amount of nitrogen may all be important.

Calibration

Remembering that perennial plants are involved, it is evident that each of the classes of field investigation described above covers two types, and the statistical design may be materially influenced thereby. One must start as soon as the trees are planted, while the second may need to be done on mature plants.

Evidently studies of varieties or rootstocks involve more than one different kind of plant, and any research that includes such comparisons must start as soon as they are planted out in the field. Further, an experiment which is designed to elucidate the interaction of, say, cultural treatment and rootstock, should also commence when the trees are planted, even though differential cultivations do not start until they are established.

On the other hand, in some instances the make-up of the plant may be irrelevant, the whole being carried out on one variety or kind of tree. In such, the experiment may not start until the plants are established and its accuracy may be greatly improved if the previous history of the plants is known and the inevitable variations that have affected them during establishment can be eliminated in the statistical analysis of the results.

Thus, herbicides may be found that, while they do no apparent damage to black currant bushes, may still affect growth or cropping. In applying such herbicides, it may be that less replication will be needed if the experiment is carried out on bushes whose previous size and cropping when mature are known and the errors thereby reduced. This device is known as ' calibration ', the plants being recorded without treatment until they are mature, when the experiment can start.

It is not the purpose of this paper to describe the method in detail, but in laying out an experimental farm it is often an advantage to plant up uniform areas of various fruit plants, initially without treatment, but which can subsequently be used for experiment, after calibration.

Land and material

Having resolved on the general pattern and provisionally decided on the varieties and treatments that it is desirable to include, there are several points that must be taken into consideration before the final design is made and the trees planted.

Land

The area and shape of suitable land available may well have a marked influence on the design. At most research institutes land for fruit growing is scarce and every acre must be used to the best advantage. On few, if any, farms are the soil, topography and elevation uniformly fitting for all perennial plants that must flower and bear fruits, though there may be parts that are useful for propagation or other trials where fruits are not required. Even comparatively short-term crops, such as strawberries, are better placed on land that is generally free of spring frosts. Some experiments must be isolated from others that may prove a source of disease, thus again limiting the land available for them.

Again, at any rate in England, it is exceptional for a field to be rectangular in shape. Nor is it often possible to adjust the shape by grubbing hedges or moving roads, since they may leave residual effects on the soil that last for many years. Thus, if an experiment calls for, say, one and a half acres of land this will generally have to be fitted into a field together with other trials, with as little wastage of land as possible. In planning an orchard for a particular field, it is as well to remember that, though on the map it may appear to have an area of, say, ten acres, by the time headlands, roads and

sometimes the effects of windbreaks, buildings, hedges or adjoining woodlands are allowed for, there will very seldom be anything like ten acres on which the trees should be planted.

On some of the older Stations most of the land on which fruit can be grown has already had fruis trees grown on it. The restoration of fertility and uniformity so that such land can be used again it a study in itself ; for the present, cultivation under uniform crops or grass for at least five years before it is used again must be recommended.

It is sometimes suggested that more space may be found on growers' farms and this may be true. Nevertheless, only on an experimental farm with a trained staff, both of farm workers and recorders, can full control of an experiment be maintained and the continuity of that control assured. Further, on a commercial holding, freedom in the selection of varieties and cultural treatments may well be curtailed, while what is gained in space may easily be lost by the inability, through distance or some other difficulty, to keep the plants under that close observation that is the essential of success.

Thus the experimenter will seldom have available all the land that he desires ; bearing this in mind, three principles should be emphasized.

(*a*) It is better to reduce the number of questions asked of an experiment rather than the number of replications needed to give definite answers to them. When a factorial experiment is analysed into separate treatment effects (i.e. main effects and interactions) it may well be that there are twenty or more of them. Of these, in the ordinary course of events (even were the treatments not applied at all), there will probably be a twenty to one chance ($P=0\cdot05$) that one such comparison is significant. With trees, there is no time to repeat an experiment to find out whether such a borderline effect is real or not, so higher odds should be aimed at.

(*b*) It is most inadvisable to try to squeeze in more plants than can receive the normal cultivations necessary for efficient growth and cropping. It is a temptation to plant double the number of plants that the ground should take when they are mature, with the intention of thinning them when they get too crowded. This may result in the removal of half the replications just when the trees are becoming interesting, leaving insufficient to give the definite answer that is required.

(*c*) Trees or bushes should not be planted so close that the treatments that are supposed to be included in the experiment become unreal.

The classic example of this is the substitution of hand-digging for tractor cultivation (because there is not room for the latter) and the assumption that, as both are forms of ' clean cultivation ', they are, therefore, the same. Similarly, it is important that there should be enough space for such a treatment as ' renewal ' pruning to be carried out exactly as it is supposed to be throughout the tree's life. Another example is the calculation of the appropriate dressing per tree of a fertilizer as if it were broadcast at a certain rate per acre, but the application of the amount arrived at within a small area around the tree. This has actually led to deleterious effects through the trees receiving far more than was ever intended.

Thus, it is well to make sure that every treatment is exactly what it is meant to be. In a directive experiment this does not mean that they must be normal commercial ones, but the experimenter must know exactly what he is doing, and be very clear about it when the time comes to interpret the results.

Material

(i) *Quantity*.—Many things may happen during the two or three years in which a tree destined for an experimental orchard is being propagated in the nursery. It is, therefore, essential to order more than the required number of trees so as to have enough material all ready for planting at the same time. This will involve making a provisional plan two or three years before planting and asking for at least double the number of trees likely to be needed.

The designer of a long-term experiment must, therefore, *look ahead*, for only by so doing can he make any selection of suitable trees when the time comes to plant. If a variety or treatment starts with one or more trees missing, the experiment may be short of those trees for twenty or thirty years, for they can never be replaced. There are quite enough accidents that may happen in an established plantation that cannot be foreseen, without starting short of trees. The statistician can devise a method of analysing the results of an experiment, allowing for missing trees ; but this is only making the best of a bad job and if one treatment has five trees instead of six, that treatment will be handicapped for the rest of its life.

(ii) *Health*.—The first thing to be thought of with nearly all fruit plants today is their virus status. At some future date it may be possible to ensure that all experimental plants are free of known virus diseases, at least at the start. Until then, it is necessary to look very carefully into the pedigree of every tree, in relation to the purpose of the investigation, for as long as the virus status is unknown or even suspect, it is always possible that the tree will not respond as it would if it were virus-free. It is the research worker's responsibility carefully to watch his trees throughout their lives in the

nursery, for only thus can he be sure that every tree with a record of disease or damage during that time shall be rejected for planting out.

In these times, fruit growing has become a science and healthy, standardized fruit plants have become a possibility. It is only through the watchfulness of the research worker that this can be attained, but in the enquiries that the complexities of modern horticultural science call for, it is always worth while.

Care in the plantation

Once a research plantation has been planted, there are many things to be thought of that need not be enlarged upon here. However, the continued need for ordinary care and attention to the trees ought to be stressed. This may sound obvious, but it is not always easy during the long life of an orchard. Accidents are always apt to happen but, if the accidents could have been avoided, they are no longer accidents but crimes. Such happenings as the wounding of the trunk by a tractor-drawn implement, the breaking of a branch by the careless pruner, inefficient spraying or the application of too much or too little fertilizer can all be prevented by taking greater care.

In the early days of this Station experiments were comparatively few, but every tree in the orchards was personally known to one or other of the small band of research workers and all that happened to it noticed and recorded. This may have been the secret of success. Forty years later, there are far more trees and other fruit plants on the farm and a specially trained staff of recorders and field assistants is available to help the research worker to obtain his records and apply his treatments. But it is the research worker himself who is ultimately responsible for telling the recorders what they should record, and he should never allow himself to become so busy that he is not aware of everything that happens in his plantation, able to supervise the application of treatments and to foresee and prevent when possible the accidents that may happen.

It is far better for each research worker to do a few experiments and do them well, so that each one will yield the desired information, than to expend time on many different enquiries, however well thought out, if he cannot give each his personal care and attention.

Summary

Some of the non-statistical considerations that should be taken into account in the planning of field investigations with fruit plants are described in the light of the land available and the time at the disposal of each research worker.

The difference between assessment trials and directive experiments is pointed out and the need for care in the selection of plant material and, subsequently, in the plantation emphasized.

POMOLOGY

MALLING 26, A NEW SEMI-DWARFING APPLE ROOTSTOCK

By W. S. ROGERS

It is proposed to release for distribution in Autumn 1958 a new semi-dwarfing apple rootstock, Malling 26, whose vigour status is between that of M.IX and M.VII. This new rootstock therefore fills an important gap in the vigour range of commercial rootstocks.

Origin.—M.26 was bred by H. M. Tydeman at East Malling, in 1929, its parentage being M.XVI × M.IX. It was one of the ' M.IX Cross ' series of rootstocks, whose early behaviour was reported by Tydeman (1, 2) and Preston (3). In the early field trials it had the index number 3436, and now, on its official release, it will be added to the Malling series as M.26.* Detailed descriptions and photographs of its main botanical features were published by Tydeman (2).

Vigour.—Figs. 1 to 3 show that, at 12 years old, Cox's Orange Pippin on M.26 has formed a tree of a convenient and manageable size, between that of trees on M.VII and M.IX.

Full details of the rootstock trials of which these trees form part were reported, up to the age of 7 years, by Preston (3). Table I summarizes the growth and cropping of Cox on M.IX, M.26 and M.VII in these trials up to 12 years old. The trees on M.IX and M.26 were in two adjoining trials, each of which also contained trees on M.VII. The figures in Table I are the means of 8 trees on M.IX (4 replicates of 2) in Trial A, of 9 trees on M.26 (3 replicates of 3) in Trial B and of the two comparable sets of trees on M.VII on both plots. Trees on M.VII in the two plots were, in fact, similar.

TABLE I

GROWTH AND YIELD OF COX'S ORANGE PIPPIN ON M.IX, M.26 AND M.VII

(MEANS PER TREE UP TO 12 YEARS OF AGE)

	M.IX	M.26	M.VII
Area of trunk cross section, sq. cm. ..	28	52	97
Height, feet	6·9	7·9	10·9
Spread, feet	10·0	11·3	15·9
Accumulated yield, lb.	195	249	312

Table I shows that the trunk cross sectional area of trees on M.26 was rather more than half that of trees on M.VII, and not quite twice that of trees on M.IX. In height and spread trees on M.26 are intermediate between those on the other two rootstocks. Because of the very spreading habit of trees on M.IX, the ground *area* occupied by them is only about 20 per cent less than that of trees on M.26. The latter, however, have at least one more tier of branches (Figs. 1–2) and are definitely larger trees.

A bulge forms at the union of trees on M.26, though not so large a one as on M.IX.

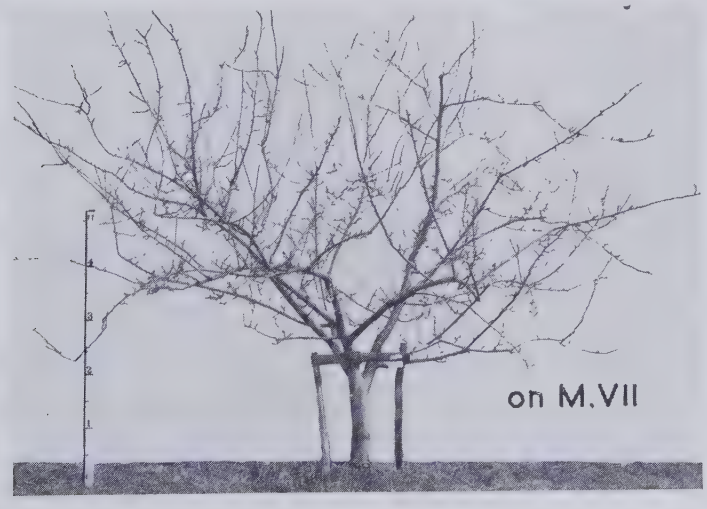
On these plots the regulated pruning system has been used, leading to rapid cropping and reduced extension growth. In commercial practice, rather harder pruning of trees both on M.IX and M.26 might be desirable. The optimum spacing will vary according to soil and pruning treatment ; a good general guide would be about 2 ft. wider apart, for trees on M.26, than would be suitable for trees on M.IX on the same soil.

The measurements of trees of Orleans Reinette, Egremont Russet and Sunset, on the same plots (figures not quoted here) confirmed the results given above.

Root structure.—Studies of the root structure of nursery trees of Cox's Orange Pippin on M.26, made by Beakbane and Thompson (4) showed that vigour rather less than M.VII, and precocity greater than M.VII would be expected ; shoot growth and fruit bud formation on the same set of trees at 3 years old confirmed these findings, which have also been supported up to the age of 12 years in the present trials.

Yield.—In the nursery trial (4) the order of precocity, judged by number of fruit buds per tree, was M.IX, M.26, M.VII. In trials A and B, trees on all three rootstocks came quickly into cropping and the larger trees had out-yielded the smaller ones by the seventh year. Thereafter, size of tree

* Because of the length and relative clumsiness of many of the higher Roman numerals, it is proposed to use Arabic numerals for rootstocks M.26 and onwards.



Figs. 1-3.
Twelve-year-old Cox's Orange Pippin trees on M.IX, M.26 and M.VII.

[*face page* 48

was the governing factor in amount of crop : even so, the accumulated yield, in relation to tree size as shown by trunk cross sectional area, still follows the descending order M.IX, M.26, and M.VII up to the 12th year. The average yield of Cox on M.26 was 47 lb. per tree, in the 11th year. In the 12th year, 1957, blossoms below a height of about 5 ft. from the ground were killed by frost, which reduced the crop of the shorter trees, on M.IX and M.26, much more than that of M.VII. The size and colour of fruit on M.26 has been excellent, slightly better, in fact, than fruit on M.IX and M.VII.

In general it is clear that in precocity and fruitfulness as well as in vigour, M.26 has been influenced more by its male parent M.IX than by its female parent M.XVI.

Anchorage.—Preston (3) has shown that the anchorage of M.26 is better than that of M.IX, though not so good as M.VII. Staking of trees on M.26 would probably be needed throughout their life.

Suckering.—Most of the ' M.IX Cross ' rootstocks tend to form many suckers in the field (3), but M.26 is good in this respect, forming fewer suckers than M.IX or M.VII. Some 11 per cent of the trees on M.26 formed suckers (3).

Nursery performance.—M.26 propagates well from stools, having a production comparable with M.VII and M.II. It also roots satisfactorily from hardwood cuttings, if given growth substance treatment and protected winter storage.

The shoot growth is strong and the larger shoots sometimes tend to be knobbly, but this has caused no undue difficulty in budding. Growth of buds and grafts has been good, a ' take ' of over 90 per cent being common. Besides the trees of Cox, Orleans Reinette, Egremont Russet and Ribston Pippin in the trials described above, hundreds of trees of Cox, Fortune and Laxton's Superb have been raised.

Laxton's Superb buds have made exceptionally strong maiden growth on M.26, and in two successive seasons a number of shoots of this variety have broken near the union in high summer winds or during the snagging process. This caused losses of over 20 per cent in 1956 and 10 per cent in 1957. Microscopic examination of these unions showed no sign of incompatibility, the unions themselves being perfect. The tissues of the young Laxton's Superb shoots on M.26 showed poor fibre formation near the bud shield, but normal fibres developed later, and no breakage has occurred in the second season in some 150 trees of this combination at East Malling. However, with this variety it would seem wise to avoid exposure to high winds or other stresses in the first season.

Virus status.—When tested by grafting with Lord Lambourne, M.26 proved free from rubbery wood and mosaic.

Fungus diseases.—No difficulty has been experienced with maintaining strong and healthy foliage in the stoolbed; scab and mildew control has presented no problems. In resistance to mildew, M.26 is about equal to M.II and M.VII, and much better than M.IX.

Laboratory tests of the resistance of M.26 to collar rot (*Phytophthora cactorum*) by Dr. G. W. F. Sewell have shown intermediate resistance, similar to that of M.XII.

Conclusion

Malling 26 should prove useful for many purposes for which small trees are required, for instance small bush trees, filler trees, or trees for experimental purposes, and cordon or pyramid trees where vigour rather greater than that of M.IX is required.

Its general behaviour in the nursery is good and it fills a unique place in the vigour range. Another, and timely, advantage of M.26 is that, whereas supplies of virus-tested M.IX have not yet reached sufficient numbers for distribution, supplies of M.26, free from rubbery wood and mosaic, will be available in autumn 1958.

Acknowledgements

I thank many of my colleagues for providing up to date information for this paper. Special acknowledgement is due to Mr. A. P. Preston, Mr. R. J. Garner and members of the Pathology Section.

Summary

The main features of a new semi-dwarfing rootstock, M.26, are described. This rootstock fills a unique place in the vigour range, between that of M.IX and M.VII.

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THE FIELD PERFORMANCE OF HEAT-TREATED STRAWBERRY CLONES

By W. S. ROGERS and MURIEL G. FROMOW

The successful inactivation of certain viruses in strawberry plants by heat therapy (3, 4) at East Malling Research Station made it possible to raise and propagate new and healthier clones of some varieties previously totally infected.

This paper describes field trials of some of these heat-treated and untreated clones. Table I shows the varieties and clones tested, with their virus content as diagnosed by aphid transmissions and graft testing to *F. vesca*.

TABLE I

VIRUS CONTENT OF HEAT-TREATED AND UNTREATED CLONES

Trial	Variety	Untreated clone		Heat-treated clone	
		Index number	Virus content	Index number	Virus content
Trial 1— planted November 1953	Huxley	M.44	Severe virus 1+virus 4	M.403	Virus 4
	Perle de Prague	M.45	Mild virus 1	—*	Virus free
Trial 2— planted October 1954	Huxley	M.44	Severe virus 1+virus 4	M.403	Virus 4
	Perle de Prague	M.45	Mild virus 1	M.404	Virus free
	Early Cambridge	—	Severe virus 1+virus 4	M.407	Virus 4
Trial 3— planted October 1955	Early Cambridge	—	Severe virus 1+virus 4	M.407	Virus 4
	Mme. Lefebvre	M.49	Severe virus 1	M.406	Virus free
	C. Prizewinner	—	Severe virus 1	M.412	Virus free
	C. Rearguard	—	Severe virus 1	M.409	Virus free
	C. Favourite	—	Severe virus 1+virus 3	M.410	Virus 3

* The heat-treated clone of Perle de Prague included in Trial 1 was similar to but not identical with M.404, which was the one released.

Experimental procedure

The plants were raised in isolated field runner beds, and selected for uniformity at planting. Trial 1 contained six fully randomized replicates of 24 plant plots. Trials 2 and 3 had four replicates of 48 plant plots, fully randomized in Trial 2 and of a split plot design for the pairs of clones in Trial 3. The planting distance was $1\frac{1}{2} \times 3$ ft.

The height, spread, and health of each plant were recorded each autumn and in Trials 2 and 3 in spring also. The runners removed from each plot in the first season were weighed.

Fruit was recorded in three grades, viz. Grade 1, sound marketable fruit of $\frac{7}{8}$ in. diameter or over, Grade 2, smaller marketable fruit, and Grade 3, unsaleable fruit mainly infected with *Botrytis* Rot or damaged by Strawberry Seed Beetle (*Ophonus angusticollis* Mull., syn. *Harpalus rufipes* (Beg.)).

Fruit was usually picked three times a week. The percentage of total yield in the first five picks of each clone was used as an indication of relative earliness, and the percentage of fruits in Grade 1 gave a measure of relative size.

Results

Most of the heat-treated clones grew more vigorously than the untreated clones ; and in some cases the yield was increased, but in others, reduced. The fruit tended to be rather later ripening and somewhat more infected by *Botrytis* Rot. The heat-treated clones tended to survive better under conditions of natural re-infection by virus in the field. No progeny of heat-treated plants have shown any variation in morphological characters from the untreated plants.

The main results are shown in Tables II and III, and are discussed variety by variety below. For brevity, data on plant height and percentages of Grade 1 and Grade 3 fruits are not tabulated but are

mentioned in the text where appropriate. Significant differences between the treated and untreated clones, at the 5, 1 and 0·1 per cent levels are indicated in the text by the abbreviations S, S2 and S3 respectively.

TABLE II

PERFORMANCE OF HEAT-TREATED (T) AND UNTREATED (O) CLONES OF HUXLEY, PERLE DE PRAGUE AND EARLY CAMBRIDGE STRAWBERRIES

Variety	Trial	Clone	Vigour		Runners	Marketable yield			Earliness		
			spread in Oct. in.		wt. removed lb. per plot	Grades 1 and 2 cwt./acre			% in first five picks		
			1st yr.	2nd yr.	1st yr.	1st yr.	2nd yr.	3rd yr.	1st yr.	2nd yr.	3rd yr.
Huxley	1	O	18·7	15·5	18	—	108	50	—	19	20
		T	20·1***	17·9**	21**	—	118†	64**	—	10***	9**
	2	O	20·8	18·2	33	15	53	87	24	14	20
		T	21·7	18·8	32	18	47	92	13***	7**	11***
Perle de Prague	1	O	21·3	20·2	14	—	93	61	—	22	12
		T	19·6***	19·6	12	—	95	74**	—	20	12
	2	O	22·9	17·7	45	18	62	72	20	22	40
		T	22·6	17·7	36**	17	65	78	18	19	38
Early Cambridge	2	O	19·8	18·0	43	19	44	104	25	28	27
		T	22·0**	19·9**	38	29***	30*	86***	22	23†	21**
	3	O	13·5	—	14	11	31	—	23	30	—
		T	14·2†	—	19**	13†	27	—	24	35	—

The yield figures are rounded off to the nearest cwt. (112 lb.).

*** Difference significant at 0·1 per cent level ($P<0·001$).
** Difference significant at 1·0 per cent level ($P<0·01$).
* Difference significant at 5·0 per cent level ($P<0·05$).
† Difference approaching significance ($P<0·1$).

Huxley

In Trial 1 the plants of the treated clone were markedly larger than those of the untreated older clone, both spread (Table II) and height being some 10 per cent greater (S2). Maiden plants of the treated clone produced 20 per cent more runners (S2).

The marketable crop was some 11 and 28 per cent greater in the 2nd and 3rd years respectively (S2), giving a combined increase of over a ton per acre. The first year crop was lost from beetle attack.

By the end of the second season virus symptoms on many plants showed that Yellow-edge had spread from an adjoining plot. Severe symptoms showed on 18·2 per cent of plants of the treated clone and 36·4 per cent of plants of the old untreated clone, showing that the latter, which were already carrying the greater quantity of virus, succumbed more quickly to further virus infection.

In Trial 2 plant size differences were smaller and marketable yields were not significantly different. The greater resistance of the treated plants to virus reinfection was again evident. At the end of the 2nd year 2·7 per cent of the plants of the treated clone and 11·0 per cent of the plants of the untreated clone showed virus symptoms. Even so, in the 3rd year the marketable yield from the treated clone was only 6 per cent heavier than from the untreated.

An apparently smaller yield from the treated clone in the second year of Trial 2 was largely accounted for by an increase in *Botrytis* Rot which spoiled 44 per cent of the fruit from the treated clone and 39 per cent from the untreated. The extra leafiness of the treated clone presumably increased the humidity around the fruits, making them more liable to rot. In Trial 1 in the same season (1956) the plants were smaller, being a year older and partly reinfected with virus, and the percentage of rotten fruit was less, but there was the same tendency towards more rotten fruits on the treated clone.

In both seasons of both trials the fruit ripened somewhat earlier on plants from the untreated

clone (Table II). This effect was also probably largely due to the greater leafiness of the heat-treated clone.

In no case was there any difference in fruit size.

Perle de Prague

The differences between the untreated and treated clones of Perle de Prague were less than those between the clones of Huxley, possibly because the old clone of Perle de Prague only contained mild Virus 1.

There was a tendency for plants of the two heat-treated clones to be less vigorous than those of the untreated clone, particularly as maidens, although this only reached significance in the first autumn of Trial 1. This was also reflected in a smaller runner production in Trial 2 (S2). By the end of the second season in Trial 2 the treated plants were 10 per cent taller although there was no difference in spread (Table II).

There were no differences in yield except in the 3rd season of Trial 1 when reinfection with virus was again becoming apparent. This variety is slow to show virus symptoms, but by that time severe symptoms were showing on 1·5 per cent of the plants of the untreated clone although on no plants of the treated clone. The latter then gave a 22 per cent greater yield (S2)—another example of the greater power of survival of the treated plants.

There were no differences in fruit size, earliness, or percentage of rotten fruit.

Early Cambridge

In Trial 2 (the first containing this variety) the heat-treated clone was strikingly more vigorous than the untreated clone (Table II). The first season's crop was 50 per cent greater from the treated clone (S3), and the fruits were larger, 64 per cent of the yield from this clone being in Grade 1, compared with 57 per cent from the untreated clone (S).

In the second season a completely different result appeared, for in that spring (1956) many crowns of the heat-treated clone were ' blind ', i.e. they failed to produce inflorescences. A count on sample plants showed 11·5 blossom trusses per plant on the untreated clone, and only 6·5 on the treated clone, the average number of crowns per plant being approximately nine in each case. The subsequent yield of the treated clone was only about two-thirds that of the untreated clone (S) (Table II).

In the third season (1957) counts on sample plants showed 27·5 blossom trusses per plant on the untreated clone and 17·4 on the treated clone, the average number of crowns per plant in each clone being 14·8. Thus while there was no ' blindness ' in that season, plants of the untreated clone had two trusses on most crowns, and those of the treated clone only one. Subsequently the yield from the untreated clone was 20 per cent heavier (S3), a difference of 18 cwt per acre.

In order to see whether reduced blossoming in the second season might be associated with overcropping in the first season, half the plants in Trial 3 were deblossomed as maidens. It was found that deblossoming increased the number of crowns per plant, but had no effect on the number of blossom trusses per crown. In both clones plants deblossomed as maidens cropped 15 per cent more heavily than those allowed to fruit as maidens.

In Trial 3 the yield of the treated clone was 5 per cent higher in the first season, and 15 per cent *lower* in the second, than that of the untreated, so repeating the trends seen in Trial 2, but a year later (Table II). The reduced crop again arose from lessened blossoming, second year plants of the treated clone usually carrying only one blossom truss per crown, against two per crown on the untreated.

As with other varieties, fruit on the treated clone tended to ripen later (Table II) and to suffer more from *Botrytis* Rot.

Further studies of fruit bud development in treated and untreated clones are discussed later.

Mme. Lefebvre

In Trial 3, plants from the treated clone of this variety again grew more vigorously. At the end of the first season such plants were 26 per cent taller (S2) and 7 per cent broader (Table III). They also produced 90 per cent more runners in the first season (S2).

Frost markedly reduced crops of this susceptible variety, in both years, making yield comparisons unreliable. Two year plants of the untreated clone flowered several days earlier and even after frost damage fruit on these plants ripened earlier (Table III).

C. Prizewinner

Differences in plant size were not so marked for this variety as for the others in Trial 3, although plants of the treated clone were rather larger (Table III).

TABLE III

PERFORMANCE OF HEAT-TREATED (T) AND UNTREATED (O) CLONES OF MME. LEFEBVRE, C. PRIZEWINNER, C. REARGUARD, AND C. FAVOURITE STRAWBERRIES IN TRIAL 3

Variety	Clone	Vigour	Runners	Marketable yield		Earliness	
		spread in Oct. in.	wt. removed lb. per plot	Grades 1 and 2 cwt./acre		% in 1st 5 picks	
		1st year	1st year	1st year (1956)	2nd year (1957)	1st year	2nd year
Mme. Lefebvre	O	14·0	10	9	21	45	25
	T	15·0	19**	8	19	43	20
C. Prizewinner	O	10·5	12	14	39	28	51
	T	10·9	14	18**	41	17**	54
C. Rearguard	O	15·9	36	7	92	28	14
	T	17·3*	52**	9**	80***	16**	9*
C. Favourite	O	12·3	16	14	73	12	33
	T	16·4***	51***	13	118***	6*	18***

The yield figures are rounded off to the nearest cwt. (112 lb.).

*** Difference significant at 0·1 per cent level ($P<0·001$).
** Difference significant at 1·0 per cent level ($P<0·01$).
* Difference significant at 5·0 per cent level ($P<0·05$).

In the first season there was a 26 per cent heavier yield from the treated clone (S) and in the second season there was a slight difference in favour of this clone. Fig. 1 shows that in the first year fruit on the treated clone was slightly later ripening, the increased yield from this clone occurring in the second half of the season. Following frost damage to the early flowers of both clones in the second year there was no difference in time of ripening.

There were no differences in fruit size, but fruit on the treated clone again showed a greater tendency to rot, particularly in 1956.

C. Rearguard

Plants from the treated clone were 14 per cent taller (S2) and 9 per cent broader (S) at the end of the first season (Table III). Maiden plants from the treated clone also produced 44 per cent more runners (S2).

The first season's yield from both clones was low, partly owing to a very high proportion of rotten fruit in the wet year (1956). In spite of the fact that fruit on the treated clone showed a greater tendency to rot, the marketable yield was some 2 cwt. per acre heavier from this clone (S2). However, in the second season a category record showed that, as in Early Cambridge, there were fewer blossom trusses per plant on the treated clone. Subsequently the yield was some 12 cwt. per acre lower than that of the untreated clone (S2). There was no difference in fruit size in the first year, but in the second season fruit on the treated clone tended to be rather larger, doubtless owing to the reduced yield. In both years fruit was slower to ripen on the treated clone (Table III. Fig. 1).

C. Favourite

Plants from the two clones of this variety in Trial III showed a very large difference in vigour. By the spring of the first season plants of the treated clone were some 37 per cent taller and broader (S3) and differences of the same order were maintained thereafter (Table III). Maiden plants of the treated clone produced some 220 per cent more runners (S3).

Difference in yield between the two clones did not occur until the second season when the treated clone outyielded the untreated by 62 per cent, or 45 cwt. per acre (S3) (Table III). In 1957, a drawn-out flowering season, the first flowers opened over a week earlier on the untreated clone, and in both years fruit from this clone ripened earlier (Figs. 1 and 2).

There were no differences in fruit size but there was 10 per cent more rotten fruit on the treated clone in the first year and approximately 50 per cent more in the third year (S).

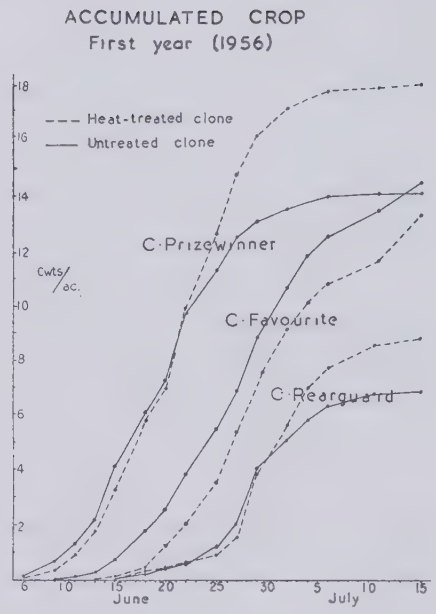

FIG. 1

Accumulated crop of heat-treated and untreated clones, as one-year-old plants, showing delayed ripening and (in two cases) higher final yield of treated plants.

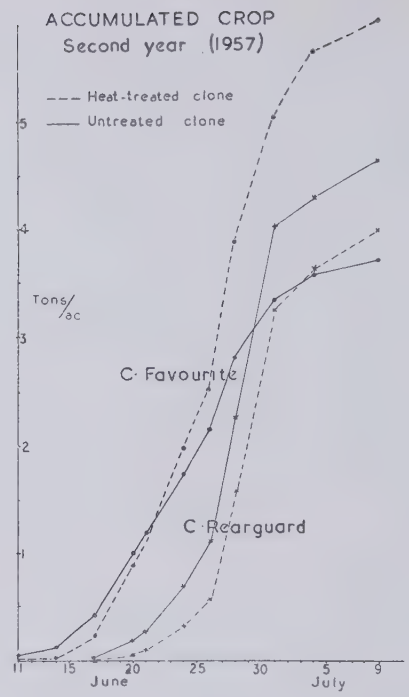

FIG. 2

Accumulated crop of heat-treated and untreated clones, as two-year-old plants, showing delayed ripening, higher final yield of treated C. Favourite and lower yield of treated C. Rearguard.

Discussion

Since no morphological differences between heat treated and untreated clones were found, it may be concluded that the increased vigour of the treated clones was due to differences in virus content. The degree of invigoration varied both with variety and with initial virus content. Differences in favour of the treated clone were greater where the untreated clone carried a combination of viruses and the treated clone a single virus (e.g. Cambridge Favourite, Early Cambridge and Huxley), than where the untreated clone contained only a single virus and the treated clone was virus-free (e.g. Mme. Lefebvre, Cambridge Prizewinner, Cambridge Rearguard and Perle de Prague)—another example of the enhanced effect of viruses in combination.

The least gain in vigour was in Perle de Prague, which contained only mild virus 1 before treatment and was virus free after ; moreover, this variety is notably virus-tolerant. The treated clone of Early Cambridge showed rather greater invigoration than that of Huxley, though both contained viruses 1 and 4 before treatment, and virus 4 after.

Becker and Rich (2) have shown that virus-free plants of certain American strawberry varieties grew more vigorously than comparable plants from commercial stocks. In the American trials the plants were grown under a matted system and the increased yield from the virus-free plants was found to be due more to an increased number of runners in the mat than to an increased yield per plant. In the present trials, with spaced plants, yield differences have been much less clear than vigour differences. Increased yield was associated with increased vigour up to a point, but beyond this it appears that further increase in growth occurred at the expense of cropping. Thus while the heat-treated clones of Cambridge Favourite and Huxley generally showed useful increases in yield, those of Early Cambridge and Cambridge Rearguard gave lower total yields than the untreated clones. This reduction in yield appears to be associated with excessive vigour rather than with heat treatment or virus freedom, for in 1956 ' blindness ' was noted in several varieties which were not heat treated, and it has been general experience that certain varieties may fail to crop, if given too much nitrogenous manure.

Dissection of about 100 buds of Early Cambridge showed that in the autumn of 1956 floral initiation occurred at least two weeks later on crowns from the treated clone than on crowns from the

untreated clone. Vegetative growth continued for two additional nodes in the treated clone, and by December, crowns of this clone had formed only a primary inflorescence, while crowns of the untreated clone had formed primary and secondary inflorescences. The fact that this difference was still present at flowering time suggests that once the plants are fully dormant in mid-winter no further initiation occurs. The second half of August and the beginning of September were unusually warm in 1955 and it is probable that the combination of short days and low night temperatures favourable to floral initiation did not occur until particularly late in that season. Since crowns of the treated clone of Early Cambridge are apparently slow to initiate flowers it is possible that in that autumn many became fully dormant before initiation could occur, resulting in partial 'blindness' the following spring. Preliminary studies also indicate that in Cambridge Rearguard initiation normally occurs late in the autumn, and a similar hypothesis would account for the almost complete blindness of both treated and untreated clones of this variety following the unusual autumn of 1955. A certain amount of blindness in the treated clone also followed the more normal autumn of 1956.

Work is in progress to see whether delay in flower initiation is directly connected with increased vegetative vigour. Arney (1) has shown that flower initiation was delayed in strawberry plants growing at a very high nitrogen level : the present trials had about 40 tons of farmyard manure per acre before planting and 10 cwt. of meat and bone meal plus 2 cwt. sulphate of potash per acre annually. It may be that lower manuring of the more vigorous clones would counteract any tendency to produce blind crowns, and be more economical.

Throughout the trials, fruit on the treated clones tended to be somewhat later ripening. This is at least partly due to greater shading by the more vigorous foliage. The effect was more marked in Huxley, Cambridge Prizewinner and Cambridge Rearguard, varieties which tend to carry their fruit under the leaves, than in Early Cambridge and Perle de Prague where the truss is more upright. Some treated clones flowered later in certain cases, and the later ripening may also be associated with later flower initiation. With mid-season varieties such as Huxley and Cambridge Favourite, the increased yield to be expected from the treated clone probably more than compensates for any disadvantage due to delayed ripening, while in late varieties such as C. Rearguard the delay might be an advantage. However where varieties such as C. Prizewinner and C. Favourite are being grown for the early dessert market, especially as maidens under cloches, delay in ripening is undesirable and has to be offset against any increased total yield. For cultivation under cloches, in which great leafiness is a disadvantage and earliness is all-important, some of the untreated clones containing mild viruses may well be more suitable than virus-free ones.

The probable longer economic life of the heat-treated clones, under field conditions of exposure to reinfection with virus, is a valuable asset. The most marked improvements in yield were seen in Trial 1 in which most reinfection occurred ; and such conditions would probably be found in many of the commercial strawberry areas.

To sum up, virus inactivation by heat-treatment gave greater vigour, which generally led to higher yields of rather later fruit ; but in a few cases greater vigour resulted in delayed blossom initiation, fewer inflorescences and reduced yields. Because of this tendency care may have to be taken in some instances to avoid excessive vigour, and field studies of each heat-treated clone are evidently desirable.

Acknowledgement

The authors wish to thank Miss Dorothy J. Wilson who was in charge of these trials until her resignation in August 1956.

Summary

1. Strawberry clones freed from certain viruses by heat therapy grew more vigorously than comparable untreated clones—the increased vigour varying both according to the varietal tolerance of viruses, and the initial virus content of the clone.

2. Yield was markedly increased in several varieties, including Cambridge Favourite and Huxley, but decreased in Early Cambridge and Rearguard. This decrease was due to reduced blossom formation apparently connected with excessive vigour. Blossom initiation was found to be later in the heat-treated than in the untreated clones of these two varieties.

3. Fruit of the treated clones was rather later ripening and showed a greater tendency to *Botrytis* Rot than that on the untreated clones.

4. The treated clones succumbed more slowly than untreated ones to virus reinfection in the field. Where reinfection was fairly rapid, as it might be in commercial areas, the treated clones showed to greatest advantage.

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ASPECTS OF ROOTSTOCK PROPAGATION

V. THE BEHAVIOUR OF ROOT CUTTINGS FROM PLANTS OF DIFFERENT AGE OF ESTABLISHMENT

By R. J. GARNER and E. S. J. HATCHER*

Propagators generally agree that nursery plants provide better root cuttings than older ones. Both Yerkes(10, 11) and Frischenshlager(1) found a marked contrast between the ready regeneration of seedling roots and the extremely shy rooting of scion varieties. Gisevius(7) compared thousands of cuttings from trees varying in age from one to forty-one years on seedling rootstocks, M.II, and M.IX, and recorded a decline in regenerative capacity as the trees matured. In seedling and clonal material the main regenerative phase persisted for about ten years, both being similar from about the fourth year. Any advantage which could be associated with the juvenile stage of the seedlings was largely restricted to the first two years after working, but from the data presented by Gisevius it is not easy to make a close comparison. One-year trees on clonal rootstocks were not included in the observations and, judging by the illustrations, there was considerable variation in cutting size at the different ages.

The present studies were designed to investigate the behaviour of apple root cuttings from parent plants of a single clone of varying age of establishment, also taking into account size. For practical purposes it was desired also to determine the yield of roots from parent plants of differing age.

Material and methods

To provide plants of five ages, in each of three seasons, 1-year layers of Malling Crab C apple rootstocks were tipped and bedded each year. The 1-year bedded rootstocks were set out over a period of seven years, each planting comprising four rows at 12 in. × 4 ft. spacing. Since older plants yield more roots than young ones, fewer of the older plants were needed, but as such plants occupy more space, those intended to remain more than three years were thinned to 2, 3 and 4 ft. in the rows, the numbers of trees left to provide cuttings for one season's planting being, in decreasing age, 16, 20, 40, 100, 200. Annual plantings of the root cuttings began in 1950 when the minimal parent age of two years was first reached, and continued until 1956.

Each spring the appropriate parent plants were lifted, the roots being cut off close to the trunk, tied in bundles and covered with soil. The roots were made into 5 in. cuttings(3), those from each source being graded in 1 mm. intervals, according to diameter at the middle. These data were a guide when selecting the grades for the experimental plantings and provided the required information on root production of parent plants.

For the first six years the cutting beds were on a terraced island(5) composed of a highly alkaline calcareous silt, with an admixture of organic matter conferring considerable moisture holding capacity. In the seventh, and final, year the cuttings were planted in a soil of the Roseacre Series, Sandgate Beds(2), a fine sandy loam, well drained in its surface layers but with a somewhat retentive subsoil. Throughout the experiment cuttings were always planted within the period 30th March–9th May, in plots of ten cuttings, replicated four times in randomized blocks, the spacing being 2 in. × 6 in. Assessment of results was based on survival, establishment, and growth during the season following planting.

Results

Root production for cuttings.—Establishment and growth of the parent plants were good. Observations and photographs made each year after lifting (Fig. 1), showed that growth was similar in plants of comparable age within the experimental period. Mean yields of root cuttings, graded according to their diameter for the three years in which the full age range was available, are shown in Table I. The younger trees had fewer coarse roots than the older ; the proportion of thick and thin roots, within the 5 to 12 mm. grades, was generally maintained after the second year ; but even in the oldest trees about twice as many cuttings of 5 to 8 mm. diameter were available as from 9 to 12 mm. The total yield of 5 to 12 mm. cuttings was nearly doubled year by year up to the fifth year, the lack of further increase from the 6-year trees being partly due to difficulty in digging up all the roots of such trees.

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TABLE I

NUMBER OF ROOT CUTTINGS OBTAINED FROM PLANTS AT DIFFERENT AGES
(MEANS OF THREE SEASONS)

Age at lifting (years)	Diameter grades (mm.)								Total cuttings per plant
	5	6	7	8	9	10	11	12	
2	2·9	2·7	1·6	0·9	0·5	0·3	0·2	0·1	9·2
3	3·4	4·5	3·5	2·3	1·7	1·1	0·6	0·3	17·4
4	4·8	6·9	6·7	4·2	3·6	2·7	1·4	1·2	31·5
5	10·3	10·7	11·5	7·0	6·0	4·9	2·4	2·5	55·3
6	5·9	11·3	10·8	6·7	6·9	6·7	3·5	3·0	54·8

Establishment and growth.—In the first four years there was considerable seasonal variation in establishment and growth of the cuttings. Thus, in 1950, 76 per cent of cuttings from 2-year parents survived, all five size grades behaving similarly, whereas in 1952 only 13·5 per cent survived, and there were considerable differences between the grades. In the three years in this preliminary period in which roots from 2-year parents were compared with those from older plants, there was an indication, clearest for thinner roots, that roots from younger parents established best.

The experiments in the years 1954 to 1956, with roots from parents of five ages, showed a highly significant ($P<0·01$) connexion between age and establishment (Table II). In each of the three years, roots from 2-year parents established best, whilst establishment of roots from older plants was usually much inferior. This decline with age is clearly seen in Fig. 2. The effect of size (thickness)

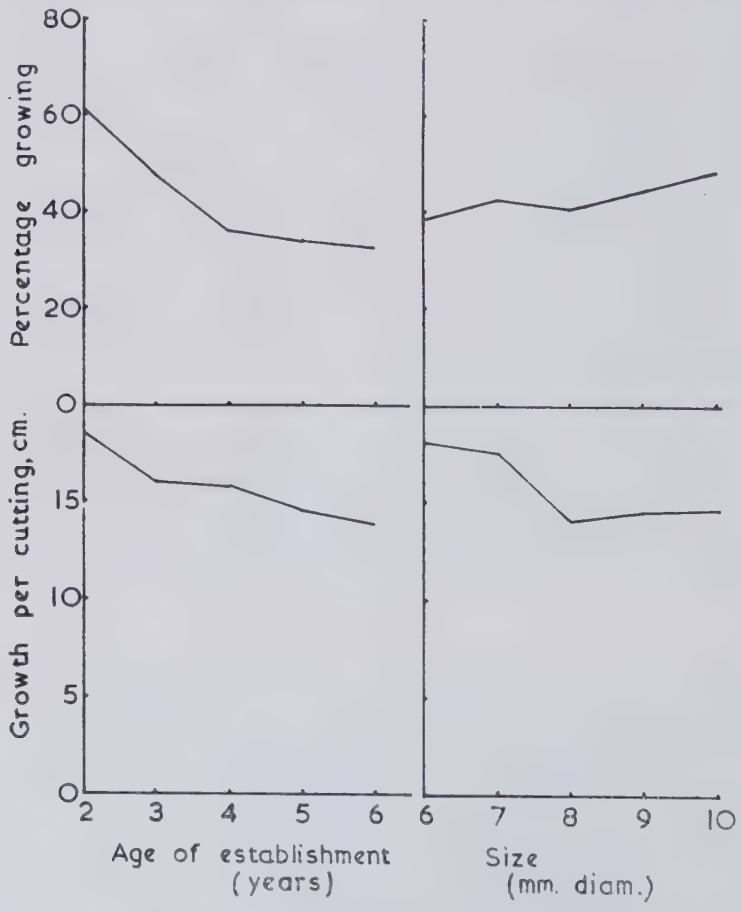

FIG. 2

The regenerative behaviour of root cuttings of Crab C according to their size and to the age of establishment of their parent plants

Fig. 1

Typical parent plants of two and six years establishment, the age range covered by the root cutting experiments

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of root is not so definite ; but in 1955 and in 1956 the thickest roots (10 mm.) established considerably better ($P<0.05$) than the thinnest (6 mm.) and in general the trend was in favour of the thicker roots.

TABLE II

THE ESTABLISHMENT (PERCENTAGE GROWING) OF ROOT CUTTINGS DIFFERING IN SIZE FROM PARENT PLANTS ESTABLISHED FOR TWO TO SIX YEARS

Age of establishment (years)	2	3	4	5	6
1954	69·0	43·5	35·5	34·5	42·5
1955	40·3	34·5	25·0	16·5	24·0
1956	75·5	65·5	48·5	52·0	32·5
Size (mm.) diameter	6	7	8	9	10
1954	43·5	43·5	42·0	50·5	45·4
1955	23·5	28·5	26·0	27·5	38·0
1956	47·5	55·0	54·0	56·0	61·5

Variations in the growth of established cuttings were not pronounced but roots taken from younger plants grew better (Table III). This was clearest in the 1956 experiment, on the normal soil ($P<0.01$), where the trend for thinner cuttings to grow best, was most definite ($P<0.05$).

TABLE III

THE SHOOT GROWTH (CM.) OF ROOT CUTTINGS DIFFERING IN SIZE FROM PARENT PLANTS ESTABLISHED FOR TWO TO SIX YEARS

Age of establishment (years)	2	3	4	5	6
1954	13·3	11·8	11·0	7·6	13·7
1955	15·0	12·3	15·1	9·5	12·5
1956	27·2	24·2	21·3	27·1	15·5
Size (mm.) diameter	6	7	8	9	10
1954	14·3	11·6	10·3	10·8	10·7
1955	14·9	13·6	11·5	12·3	12·1
1956	25·1	27·8	20·4	20·7	21·2

Discussion

The present experiments show that a thicker root cutting survives and establishes better than a thin, indicating a mass relationship and recalling the better survival of longer root cuttings observed by others(9). Once established, however, thinner cuttings usually grow better.

Age of parent is a major factor in regeneration of root cuttings, the youngest parents providing the best material. There is a decline in establishment and, in less degree, in new shoot growth, both being independent of size of cutting. Furthermore the rapid decline in regenerative capacity in the earlier years after establishment of the parent (Fig. 2) suggests that roots from 1-year parents might have given even higher stands, though their yield of cuttings would be small. In practice it would be necessary to compromise between having a few roots of high regenerative power and many roots of lesser quality, the optimum age for the apple rootstock Crab C being three to four years.

There is close similarity between the falling off of regenerative power with age in the clonal root system and that observed in seedling root systems, as is evident from a comparison of the Crab C findings with the data of Gisevius (7) plotted in Fig 3. In a seedling this is an expression of its juvenility, and the parallel in the mature clone suggests that roots may at formation in a stem be inherently juvenile with regenerative capacity largely restored. Conversely, Stoutemyer (8) showed that shoots newly formed from root tissues root readily like seedling shoots, again with subsequent decline in regenerative power, and this was confirmed with Crab C (4). In Stoutemyer's opinion the readiness to form roots is associated with adventitious origin, not only when a shoot meristem forms in roots, but also when formed adventitiously in stems, as from sphaeroblasts, likewise observed in

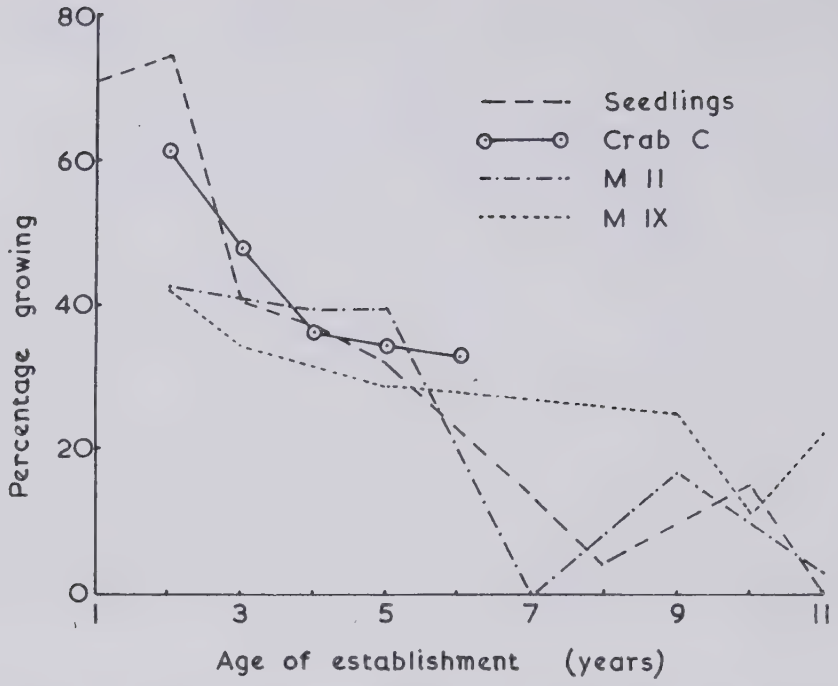

FIG. 3

The regenerative behaviour of apple cuttings of Crab C compared with similar data on seedling and clonal rootstocks obtained by Gisevius (1950)

Crab C (6). This resemblance to the seedling in regenerative behaviour strongly suggests that adventitious origin whether of root or shoot involves true rejuvenation in the formation of the new meristem. The aim of further observation will be to assess with more precision the extent of such rejuvenation.

Summary

The behaviour of root cuttings of the apple clone Crab C taken from source plants of five ages was compared in three successive seasons.

Rooting and the growth of root cuttings both declined with increasing age of establishment of the parent plant.

The effect of cutting size, within the limits compared of 6 to 10 mm. diameter, was only moderate, with thick cuttings having the better chance of survival ; but, once established, thin cuttings grew better.

The decline in rooting with age in the clone bears close resemblance to that found in seedlings, suggesting that root tissue when first initiated may have something of the quality of juvenility. The implications of this possibility are discussed.

For nursery purposes 3- or 4-year parents provide cuttings adequate both in quantity and regenerative quality.

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DEVELOPMENTS IN SOFT FRUIT BREEDING AT EAST MALLING

By R. L. KNIGHT and ELIZABETH KEEP

Raspberries

Until recent years, virus diseases were causing such havoc in raspberry crops in Britain that a continuous production of new, and therefore relatively healthy, varieties was essential. This necessity was an over-riding influence in raspberry breeding policy until the release, between 1942 and 1950, of a range of new varieties bred by Grubb(8, 9) at East Malling. Grubb's seedlings, which included Malling Promise, Exploit, Jewel, and Enterprise, not only provided a series of more or less virus-free types, but were a big advance in fruit size and yield, and in virus tolerance.

The re-introduction of a relatively virus-free stock of Lloyd George from New Zealand(10), helped to lessen this need for a rapid production of new types, and the use of heat therapy to eradicate virus(6) will make it possible to bring back into circulation other varieties in which viruses are beginning to take their toll.

These advances have lessened the immediate need for new varieties, so that a longer-term approach to raspberry breeding is now possible.

The raspberry is generally regarded as depending for its yield on ' hybrid vigour ' and although this generalization is not always true, there is no doubt that breeding for hybrid vigour is one of the surest ways of obtaining high yield potential in raspberries. The standard method of using hybrid vigour is by inbreeding certain lines for several generations to get purity for desirable characteristics, and then, by inter-crossing, to regain yield capacity. The drawback of this technique is that the qualities of hybrids are strictly limited by the genes present in their parents, and no commercial variety carries the genes for all the characters required in an ideal raspberry. This programme has therefore been planned to deal with a deliberate breeding of *parents*, not by merely selfing down a range of varieties and accepting the best material in each as a parent type, but by deliberately adding desirable characters from a range of ' donor ' parents to inbred lines.

The work thus comprises three distinct phases : (a) selection and inbreeding of suitable parent lines, with intense reselection in each generation of selfing ; (b) searching for sources of additional genes required in these lines, and their transfer to these potential parents ; and (c) breeding commercial varieties by intercrossing these synthesized parents, or by crossing them with other varieties. The selection criteria used in phase (a) include agronomic characters as well as processing and dessert qualities. The hybridization in phase (c) is followed by further selection to ensure that the optimum expression of each character is obtained.

At present three parent lines selfed for two or more generations, and six lines in their first generation of inbreeding, are available. Of the three 'established ' lines, one, in its third inbred generation, is more or less pure for large fruit and is known to impart high yield potential to its hybrids. This line and subsequent selfs from it will be referred to as P1. A second line, P2, from Reid's Seedling AR.1 (a self of Burnetholm), has now been inbred for two generations : it is homozygous for absence of thorns, and carries genes for excellent flavour. The third family, P3, derived from Norfolk Giant, is pure for lateness and for regular shaped fruit with small drupelets. The six lines at an earlier stage of inbreeding include types with outstanding flavour, others with large well-shaped fruit combined with good flavour, and one family carrying very high yield potential.

The characters being transferred to the three primary lines include : resistance to the *Rubus* Aphid (*Amphorophora rubi* Kalt.), to Cane Spot (*Elsinoë veneta* (Burkh.) Jenk.), and to virus; thornlessness ; hairiness of the cane ; autumn fruiting ; dwarfing habit ; male sterility ; and flavour and firmness of fruit.

Such transferences involve moving one or a strictly limited number of genes from the donor parent to some or all of the inbred lines without at the same time transferring extraneous genes likely to be disadvantageous ; the basic character of the inbred line should remain unaltered. These transferences are made by repeated backcrossing, selecting in each generation, for further backcrossing, a plant carrying the gene being transferred.

Transferences of recessive genes are usually best done on the basis of cross, backcross, self, backcross, backcross, self. The selfing is necessary after every second generation of crossing in order to find and select the plants carrying the recessive gene.

In dealing with the transference of gene-complexes, it is essential to self after each generation of crossing, in order to re-integrate the complex by selecting for maximum expression of the character

in each inbred generation. This is an adaptation of the technique used by the senior author in inter- and intra-species transferences of gene complexes in cotton(12).

Resistance to *Amphorophora rubi*

More than a dozen viruses attack the raspberry plant in this country and the most important vector of these is the *Rubus* Aphid, *Amphorophora rubi*. There are two ways of breeding for freedom from virus : (1) selecting for resistance or tolerance to all the important viruses involved, or (2) breeding for virus avoidance by using resistance to the vector. To search for resistance to a large number of viruses and to transfer each resistance to the inbred lines would obviously be a lengthy process, and although breeding for direct virus resistance is being carried out, work on vector resistance is likely to give quicker results.

That resistance to the *Rubus* Aphid exists, was known from earlier work by Dicker and Briggs (unpublished) at East Malling, and by Kronenberg and de Fluiter(15) in Holland. Because these workers had found Malling Landmark to be resistant, this variety (and its parent, Baumforth A) was chosen as one of the main sources of resistance. Various other sources are being used, including *Rubus henryi* Hemsl. and derivatives of American raspberry varieties, but because the Baumforth A resistance was found to be genetically simple, this line has remained the keystone of the work.

Parallel with the transference of this resistance to the basic inbred parents, a field investigation was undertaken to make sure that this degree of resistance is likely to be adequate over a range of environments(14). Two derivatives of Baumforth A, namely Landmark and 64/2, were surveyed at fifteen different sites in south-eastern England and Scotland. In each case a susceptible variety, Promise, was growing nearby so that this could be used as a control. At three of these sites the counts were made on replicated trials, but at the other sites there was no replication. A standard sampling technique was used in assessing aphid populations.

For the purposes of this investigation, Landmark and its derivative 64/2 can be regarded as one ' variety ', since both carry the same resistance gene derived from Baumforth A. Totals of the counts made over three seasons on fourteen of these trials are summarized from the paper by Knight, Keep and Briggs(14) in Table I, as are counts of 64/2 and its susceptible sister variety, 64/53, made at four of these sites.

TABLE I

AMPHOROPHORA RUBI POPULATIONS ON RASPBERRY VARIETIES

	Total No. of aphids	No. of leaves of each examined	No. of sites examined
Resistant variety	253	2,632	14
Susceptible variety	7,977		
64/2	28	818	4
64/53	3,086		

Clearly the Baumforth A level of resistance could be used to reduce populations of *A. rubi* to a level at which the spread of virus would be markedly reduced, provided no aberrant strains of the aphid arise. Counts made at the fifteenth site, Ryarsh, showed an aberrant strain to be present. Here totals of six counts showed cumulative populations on Landmark and Promise of 972 and 6,341 respectively (based on 915 leaves of each). Knight, Keep and Briggs consider it probable that all of the 253 aphids found in discrete colonies on resistant plants at the other 14 sites were of this aberrant strain but that only at the one site were conditions suitable for the strain to spread more widely. The Ryarsh race of *A. rubi* has a markedly poorer level of survival than the normal strain, so that it may not be necessary to breed against it. Should it prove of economic significance, however, a source of resistance has already been located and the first backcrosses have been made in transferring this resistance to the P1 parent line.

Crosses of Baumforth A with susceptible types, and backcrosses to such types, segregate in straightforward ratios of 1 resistant to 1 susceptible, showing that resistance is controlled by a single partially or fully dominant gene, designated A_1(14). It has been shown that A_1 is linked with the ' normal ' allele of a semi-lethal dwarfing gene designated ' frilly ', and that these two loci have a cross-over value of approximately 3·3 per cent.

In the transference of the gene A_1 to the large fruited P1 parent, the second backcross was made in 1957 ; two more backcrosses will probably be required to complete this transference.

Virus resistance

No attempt is being made as yet to breed for resistance to individual viruses, but rather to the general ' complex ' of viruses common in the crop in this locality.

The American variety Newburgh has shown high virus resistance or tolerance over a ten-year period in a replicated variety trial at East Malling. That this resistance is not a localized phenomenon is shown by reports from elsewhere in England, from Scotland, and from North America. In New York State, Newburgh is recorded as showing marked resistance to Red and Yellow Mosaic(1) and to be ' mosaic escaping ' (2) ; in Washington it remained virus free although growing alongside infected Cuthbert for four years(3) ; Cadman and Wood(4) describe it as ' highly virus tolerant ' in Scotland, and Cadman(5) was unable to graft-transmit moderate and severe vein chlorosis viruses to Newburgh. On the other hand Slate and his co-workers(17) note that although Newburgh is rarely infected with mosaic, when it is the symptoms are distinct. Occasional plants with mosaic symptoms have been found at East Malling also, but such symptoms have always been rather ill-defined and there has been no marked loss of vigour. Thus it would seem that this variety carries high resistance, as well as tolerance, to an important group of viruses. That this resistance is heritable is proved by the marked resistance found in a number of hybrids of Newburgh with the susceptible line P1. Clonal material of ten such hybrids was included with Newburgh in the ten-year trial mentioned above, and eight of them, including Promise and Exploit, showed resistance approximating to that of Newburgh. These eight have continued to crop well over the period, whereas virus has spread through the other two rapidly and completely. The occurrence of both resistant and susceptible types in this one hybrid family shows Newburgh to be heterozygous for its resistance, and suggests that the genetic control of resistance is relatively simple.

The susceptible parent, P1, which was used in these crosses with Newburgh, was a self of a seedling derived from Pyne's Royal and Lloyd George. This line has since undergone two more generations of inbreeding. Promise (Newburgh × P1) is being crossed back to P1, and further backcrosses will be made as steps in the process of transferring virus resistance from Newburgh to this inbred line.

Thornlessness

Apart from the obvious advantages in ease of handling, thornlessness should greatly reduce mechanical damage to fruit by high winds. This character, controlled by a recessive gene from the variety Burnetholm, is being transferred to the basic parent types. This transference is facilitated by the fact, first noted by Lewis(16), that homozygous thornless plants can be detected by the absence of glandular hairs on the cotyledons, so that where families are segregating for this character, the thorny plants can be discarded almost as soon as they germinate.

Hairiness

A survey of two replicated variety trials over recent years has shown a marked reduction in *Botrytis* on canes of hairy-caned varieties. Since in a wet season much of the crop may be lost through direct attack of the fruit by *Botrytis* Rot, any reduction in the source of spores should be advantageous. It seems unlikely that intrinsic resistance (that is, tissue resistance) to *Botrytis* exists in the raspberry cane, and it is probable that hairiness operates by conferring some form of mechanical avoidance.

Hairiness of the cane is controlled by a dominant gene(7), and this is being incorporated in the inbred lines.

Autumn fruiting and dwarfing characters

Autumn fruiting varieties are being bred to extend the season of the crop. To reduce costs of production, this character is being incorporated in varieties having short, firmly erect canes which would require no support. Grown solely for their autumn crop, such varieties could be pruned quickly and easily by cutting down all old canes in early spring before the new ones appear. This treatment would have the added advantage of preventing spread of diseases from old canes to new.

Present-day autumn-fruiting varieties bear their autumn crop from September onwards, so that the fruit is usually damaged by gales and frost. To obtain greater earliness, the earliest tip fruiting segregates have been selected in selfed families of Romy, Lloyd George, Durham, Baumforth A, and from a line of *Rubus occidentalis* L., and these are being used as donor parents in backcrosses to the basic parent lines.

Rubus arcticus L., which flowers on annual shoots, has also been crossed with the P3 line in the hope that the annual flowering tendency will appear either in F_1 or in F_2, so that it can be transferred to a raspberry ' background ' and provide an additional source of earliness in the autumn crop.

A dwarfing character is being incorporated into some of the autumn flowering lines to give stiffly erect plants of medium height.

Male sterility

Burnetholm is heterozygous for sepaloidy(16) or male sterility, and the P2 line, derived from this variety, also carries this recessive gene. The character segregates in straightforward ratios, and it may be of value in facilitating breeding work and in the production of hybrid seed from inbred lines.

Currants

Neither the staff position nor the amount of land available at East Malling, would allow of *Ribes* breeding being regarded as a major project. Moreover, both Tydeman(19) and Spinks(18) agree that no major improvement is likely to be made by straightforward selection and hybridization within the black currant crop, except perhaps in season of ripening. For these reasons, work at this Station is being concentrated on inter-species crossing ; in addition, certain black currant varieties are being inbred for use as parents.

Possible improvements in black currants include : longer strigs, reduced running off, larger fruit, and increased distance between the fruiting branch and the first fruit, to facilitate picking.

Strig characters

In 1930, Tydeman attempted to improve strig length by crossing *R. nigrum* L. with *R. longeracemosum* Franch., the racemes of which are 12-18 in. long. The F_1 was completely sterile, but in 1957 four seeds were obtained from clonal derivatives of this hybrid growing near a group of black currant varieties. Attempts by the authors to double vegetative parts of the F_1 plant with colchicine have given several shoots which look polyploid or mixoploid, but these have not yet flowered.

A second source of improved strig characters is the red currant, as this has longer strigs with more fruit and a longer ' handle ', and is less prone to running off than the black currant. As a first step, Baldwin was crossed with a seedling red currant having approximately 20 flowers per strig and not subject to running off. Of the 308 hybrid seeds sown, 60 germinated giving a family showing extreme segregation in habit and leaf shape, with a range in vigour from dwarfs so small that they are only just viable, to plants with apparently normal growth. Half of these plants were colchicined in the cotyledon stage because a high degree of sterility was anticipated. One tetraploid plant has been obtained from this treatment. This will be backcrossed to Baldwin to transfer improved strig qualities.

In addition, *R. multiflorum* Kit., which has up to 50 flowers per raceme, and its hybrid *R. koehneanum* Jancz. (*R. sativum* Syme × *R. multiflorum*) are being used as ' donors ' for improving the number of flowers per strig. Ninety-nine seeds were obtained by crossing *R. multiflorum* with Baldwin but none of these germinated. On the other hand, crosses of *R. koehneanum* with red currant varieties yielded a total of 264 seeds from which 117 plants were obtained, and a similar number of crosses of *R. urceolatum* Tausch. (*R. multiflorum* × *R. petraeum* Wulf.) with the same varieties yielded 27 seeds from which eight plants were obtained. Any segregates in these families which show an increased number of fruit per strig may be of direct economic interest as new commercial red currant varieties, but will also be used as ' donors ' in crosses with black currants.

Fruit size

In breeding for larger fruit in the black currant, the most promising source of fruit size genes seems to be the gooseberry. Hybrids between black currants and gooseberries are invariably sterile, but by treating hybrid seedlings with colchicine, fertile allotetraploid plants have been obtained(13). These are of no direct commercial value, but represent a starting point in breeding diploid black currants carrying size genes derived from the gooseberry. Initial ' backcrosses ' of the allotetraploid using Baldwin as female parent have given some 650 seeds and, in addition, 250 seeds have been obtained from various tetraploid black currant plants crossed with the allotetraploids. Final backcrosses will all be to diploid material to re-establish the diploid condition.

In addition, tetraploid black currants crossed with large fruited diploid gooseberries have given 310 seeds. These should give triploid plants of BBG composition (using B and G to represent black currant and gooseberry genomes respectively). It is intended to colchicine these to produce hexaploids, which on crossing with diploid currants would give tetraploids of BBBG composition. It should be possible to re-establish the diploid condition by repeatedly backcrossing such plants to diploid currants, although one generation of crossing with a tetraploid form might first be necessary.

Gooseberries

The most outstanding disadvantage of all commercial gooseberry varieties is their spininess, and attention is therefore largely concentrated on breeding for the elimination of spines. In addition, a limited number of varieties are being inbred for use as parents.

In all varieties so far selfed, a marked reduction of spines has only been achieved in conjunction with a general reduction in vigour ; no truly spineless plant has ever been recorded.

Hunter(11) crossed *Ribes oxyacanthoides* with an English gooseberry and ' backcrossed ' a thornless segregate from the F_2 on to the American variety Mabel. From this cross a range of seedlings with greatly reduced spines was selected, one of which was released under the name Spine-free. This Station was supplied by Hunter with six semi-spineless seedlings derived from a cross of Spine-free with the English variety Clark. In all of these the fruit was too small for the English market. One of Hunter's six seedlings was crossed with Lancashire Lad and gave a progeny, all of which were spiny as young plants. In their third season, however, they showed a marked reduction in spininess. These hybrids proved almost completely self sterile, so that it has not yet been possible to recover in homozygous form the gene or genes responsible for reduced spines. However, one of these plants was crossed with Whinham's Industry, and a large progeny from this cross has been raised with a view to isolating larger-fruited semi-spineless forms.

A second source of spinelessness is the black currant. As mentioned earlier, doubling black currant × gooseberry hybrids with colchicine has given fertility, and these allotetraploids have been ' backcrossed ' to cultivated gooseberry varieties as a first step in the transference of the spineless character. Five such ' backcross ' plants have so far been raised, and all are spineless, apart from weak hair-like spines on the juvenile growth. None of these plants has yet flowered.

A further 194 seeds from crosses between gooseberry varieties and the allotetraploids have since been obtained. Triploids of BGG composition from these first ' backcrosses ' will be colchicined to form hexaploids, which, on crossing back to diploid gooseberries, should give tetraploids of BGGG type which could be crossed once with tetraploid* gooseberries and thereafter backcrossed to diploid types to re-establish the diploid condition and give, as an end point, spineless commercial gooseberries.

Summary

The production of a range of large-fruited high-yielding virus-tolerant raspberry varieties by N. H. Grubb, the re-introduction of a relatively virus-free stock of Lloyd George from New Zealand and the use of heat therapy to free plants from virus, have jointly lessened the immediate need for new, and therefore relatively virus-free, varieties and have made possible a longer term approach to raspberry breeding. Inbred parent lines, regarded as foundation stocks, are being built up by adding to them, by backcrossing, specific characters from a range of ' donor ' parents. The characters being transferred include : resistance to the *Rubus* Aphid (*Amphorophora rubi*), to Cane Spot (*Elsinoë veneta*), and to virus ; spinelessness ; hairiness of the cane (apparently associated with avoidance of *Botrytis* of the cane) ; autumn fruiting ; dwarfing habit ; male sterility ; and flavour and firmness of fruit. The resulting synthesized parents will be intercrossed, or crossed with named varieties, to give commercial types.

In black currant and gooseberry breeding, attention is concentrated on inter-species crossing, using colchicine to confer fertility on otherwise sterile F_1s. Such interspecific F_1s are not regarded as an end point, but as the first step in transferring desirable characters to commercial varieties. It is thus hoped to improve certain strig characters of the black currant by transferring genes from *Ribes longeracemosum* and from the red currant, and to improve black currant fruit size by transference of size genes from the gooseberry. In the reverse direction, the spinelessness of the black currant is being transferred to the gooseberry. Several black currant × gooseberry hybrids have already been made, doubled with colchicine, and backcrossed to the gooseberry and to the black currant.

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THE BREEDING OF LATE FLOWERING APPLE VARIETIES

By H. M. TYDEMAN

Damage to fruit blossoms from late spring frosts probably constitutes the greatest single hazard for fruit growing in this country, severe frost losses being sustained in particular localities in almost every year.

Because of the more widespread culture of the apple in England, the problem of frost prevention in this fruit has aroused most interest. Progress has been made in mitigating the effects of extreme cold during flowering, but the most promising long-term results are likely to be obtained by breeding for frost resistance or evasion.

Varietal differences in the resistance of apple flowers to frost are small ; no variety is very resistant, and only a few, mostly of Continental origin and only grown on a limited scale, open their flowers late, well after the period of maximum danger from spring frosts. None of these is, however, of good quality or appearance compared with commercial kinds. If late flowering could be combined with high fruit quality and attractive appearance, heavy losses from frost might be prevented, thereby making possible a considerable extension of fruit planting.

Schmidt(1) studied the progenies from crosses of the late flowering varieties Königlicher Kurzsteil and Weisse Winter Taffetapfel with several sorts flowering at the normal time. Schmidt's families were, in most cases, too small for definite conclusions to be drawn, but he pointed out the probable correlation in his seedlings between season of leafing out and time of flowering, and he considered that the characters late flowering and good quality could be combined.

Breeding work at East Malling

Breeding for late flowering combined with other desirable horticultural qualities began in 1953. Cox's Orange was chosen as the main source of quality and of most of the other desirable horticultural characters, lateness of flowering being obtained from a range of late-flowering types. In planning the scope of the work it was decided to cross Cox's Orange with these later varieties and from the progenies to select only those seedlings that leafed out late in the spring for growing on to the fruiting stage. Families of up to two thousand seedlings each were to be obtained where possible ; and the parent varieties used in the crosses were to be selfed both to provide information on their genetic constitution, and inbred lines for further breeding.

A study of the large collection of apples in the National Fruit Trials was made with the collaboration of the Director, Mr. J. M. S. Potter, and about ninety varieties were selected as being late flowering. These were established at East Malling as framework grafted trees in 1950 and as cordons in 1953 and data were collected on their times of flowering during the subsequent years. Only about thirty proved sufficiently late to be of value for breeding. The best known in this country are Crawley Beauty and Court Pendu Plat, the latter having numerous variant forms of which Königlicher Kurzsteil, used by Schmidt, is one. Several varieties, such as Edward VII, Orleans Reinette and Royal Jubilee, despite their reputation for late flowering, proved much earlier than was expected.

Data on the flowering times of these varieties in relation to that of Crawley Beauty over the six year period 1952-57 are given in Table I, varieties being arranged in order of their season as shown by the average flowering date calculated for the three years 1955-57, the only years for which records are available for all the varieties. The dates of full bloom are those on which 50 per cent of the flowers were fully open or over. In 1952 this information was collected at the National Fruit Trials at Wisley and subsequently at East Malling.

The breeding work was largely carried out in an insect-proof orchard house using trees grown in pots ; when crosses were made on trees out of doors the flowers were protected with paper bags. In certain cases, flowers were sprayed with β-naphthoxyacetic acid to facilitate setting. Details of the self- and cross-pollinations made during the period 1953-57 are shown in Table II. Of 25 crosses involving Cox's Orange Pippin as the seed parent, 17 were with named varieties chosen for their late flowering habit, two with seedlings selected for late flowering and five with species of *Malus*, four of which were markedly late flowering. In addition, eight crosses have been made using either Court Pendu Plat, Crawley Beauty or Edward VII as the seed parent. Of the pollen parents Malling XVI is notably late flowering though its fruits are of inferior size and quality. Beauty of Bath, Irish Peach and Kidd's Orange Red, although not late flowering, were included on account of other desirable qualities.

In general, the varieties used as pollen parents proved compatible with Cox's Orange although

TABLE I

DATES OF FULL BLOOM

	Flowering dates expressed as days after 30th April						
	1952	1953	1954	1955	1956	1957	Av. 1955-7
Cox's Orange	6	6	12	9	12	1	7·3
Tydeman's Late Orange	6	7	17	7	14	1	7·3
Orleans Reinette	16	8	14	12	14	11	12·3
Higham Beauty	14	13	15	25	14	6	15·0
Edward VII	11	14	18	25	17	6	16·0
Laxton's Royalty ..	13	15	—	24	20	10	18·0
Rome Beauty	8	—	—	27	18	10	18·3
Royal Jubilee	6	11	17	26	22	8	18·6
Bellefleur Longue ..	10	18	15	24	21	13	19·3
Brabant Bellefleur ..	10	19	20	24	21	13	19·3
Court Pendu Plat ..	20	14	17	26	22	12	20·0
De Jaune	10	16	21	27	20	13	20·0
La Nationale	14	16	—	29	20	12	20·3
Cusset Blanc	19	17	25	27	23	16	22·0
Normande	14	18	22	31	22	13	22·0
Gros de Jaune	17	17	17	27	20	22	23·0
De Ferlens	19	22	16	33	24	13	23·3
Cravert Vert	17	20	26	29	23	19	23·6
Suffolk Grower	14	—	27	28	19	24	23·6
Rouget de Claron ..	14	16	19	33	23	16	24·0
CRAWLEY BEAUTY ..	17	16	26	27	20	26	24·3
Reinette de Vigan ..	15	18	25	28	25	20	24·3
Cravert Rouge	17	21	27	30	23	22	25·0
Fleuretard	17	18	—	27	25	24	25·3
Médaille d'Or	—	—	28	31	22	24	25·6
Reinette de Chatelandreau	15	17	—	29	25	29	27·6
Madame Rouge	20	16	21	33	23	27	27·6
Verallot	16	—	—	31	24	29	28·0
Louiton	20	—	—	34	24	27	28·3
Canada Blanc	17	17	28	29	24	34	29·0
Sebin	18	—	—	32	28	29	29·6
André Briollay	15	20	26	33	28	31	30·6
Camuzat	17	19	28	32	29	34	31·6
Blanc Dur	17	22	27	33	26	38	32·3
Spätblühender	—	—	32	41	35	34	36·6
Paradis	24	16	23	37	29	45	37·0

the reduction to only three flowers per truss before pollination doubtless increased the proportion set (Table II). Of a total of 103,363 flowers crossed, 7,907, or 7 per cent, set fruits in the 33 crosses shown. Edward VII and Orleans Reinette (and to a lesser extent Court Pendu Plat) proved somewhat incompatible when crossed with Cox's Orange. So far as is known, all the varieties used are diploid and they produced pollen plentifully.

Self-pollinated seedlings have been obtained from twelve varieties. Their production has usually proved laborious, Cox's Orange, in particular, being highly self incompatible, only 1,195 seeds having been obtained from the selfing of nearly 60,000 flowers in spite of the use of β-naphthoxy acetic acid to assist setting. Seed production in these selfs is on a much lower level than in the crosses and a considerably greater proportion of the seeds obtained are inviable. Because of their great potential value, however, it is considered worth persevering with this part of the work.

Time of leafing out in the spring

Late flowering itself is not a satisfactory selection character because of the vast amount of work and of land that would be required to carry large populations through to flowering. Schmidt's(1) tentative conclusion that season of leafing out in the spring is connected with season of flowering, suggested the use of the former as the main selection criterion. That this approach was justified is shown by the fact that the figures for average flowering date (Table I) of the parents, graphed against the percentage of late and very late leafing out plants in the progenies tested in Table III, show a correlation coefficient of $r=0{\cdot}73$. Too much weight should not be given to this correlation, however, until further data are available, but it suggests that it is possible to select out the potential late flowerers from populations of seedling apples several years before they produce their first flowers.

Table II

Details of self- and cross-pollinations with late flowering apple varieties

Parents	No. of flowers pollinated	No. of fruits set	Percentage set	No. of seeds derived	No. of seedlings obtained
Self-pollinated families					
Blanc Dur selfed	912	55	6	239	101
Camuzat selfed	2,430	127	5	402	184
Canada Blanc selfed	1,842	59	3	138	56
Court Pendu Plat selfed	25,903	542	2	2,086	1,052
Cox's Orange Pippin selfed	58,837	570	1	1,195	295
Cravert Rouge selfed	8,798	256	3	332	195
Crawley Beauty selfed	16,995	410	2	1,391	1,071
La Nationale selfed	1,241	92	7	365	268
Madame Rouge selfed	1,547	61	4	169	83
Médaille d'Or selfed	640	214	33	402	240
Spätblühender selfed	72	42	58	144	22
Worcester Pearmain selfed	1,248	14	1	71	42
Totals	120,465	2,442	2	6,934	3,609
Cross-pollinated families					
Cox's Orange Pippin crossed with :					
André Briollay	1,473	58	4	407	345
Blanc Dur	2,769	346	12	2,509	2,200
Camuzat	4,188	380	9	2,667	2,312
Canada Blanc	2,388	362	15	2,502	2,236
Court Pendu Plat	11,087	555	5	3,923	2,258
Cravert Rouge	3,113	603	19	4,232	2,477
Crawley Beauty	2,427	514	21	3,550	2,933
Edward VII	10,138	183	2	853	586
Fleuretard	3,771	454	12	2,827	2,180
La Nationale	6,673	498	7	3,381	2,218
Madame Rouge	4,157	433	10	2,740	2,097
Malus angustifolia	126	0	—	—	—
M. coronaria	80	0	—	—	—
M. crataegifolia	120	3	3	16	8
M. ioensis	166	0	—	—	—
Malus (unnamed)	3,241	353	11	2,483	2,049
Médaille d'Or	5,439	432	8	2,821	2,354
Orleans Reinette	2,718	30	1	162	96
Reinette de Chatelandreau	2,152	106	5	793	669
*Reinette du Mans	2,082	131	6	969	811
seedling (D'Arcy Spice, open pollinated)	111	18	16	118	78
seedling (Crawley Beauty × Cox's Orange)	3,654	333	9	2,302	1,608
Spätblühender	4,696	430	9	2,973	1,666
Suffolk Grower	3,583	104	3	458	109
Tydeman's Late Orange	7,225	434	6	2,737	1,595
Totals	87,577	6,760	8	45,423	32,885
Court Pendu Plat crossed with :					
Edward VII	3,834	106	3	742	449
Kidd's Orange Red	2,321	142	6	1,208	1,039
Totals	6,155	248	4	1,950	1,488
Crawley Beauty crossed with :					
Beauty of Bath	714	6	1	23	18
Court Pendu Plat	5,347	413	8	2,461	1,479
Edward VII	2,527	219	9	1,171	605
Irish Peach	162	20	12	68	59
Malling XVI	425	152	36	907	676
Totals	9,175	810	9	4,630	2,837
Edward VII crossed with :					
Crawley Beauty	456	89	19	106	48

* Synonymous with de Jaune.

Table III

Time of leaf break in apple seedlings

Family	Total number of seedlings	Time of leaf break in the spring							
		Early		Midseason		Late		Very late	
		No.	Per cent	No.	Per cent	No.	Per cent	No.	Per cent
Cox's Orange Pippin selfed	189	62	33	118	62	7	4	2	1
Crawley Beauty selfed	511	23	4	204	40	127	25	157	31
Court Pendu Plat selfed	657	55	8	201	31	212	32	189	29
Camuzat selfed	83	0	—	12	14	10	12	61	74
Cox's Orange × Tydeman's Late Orange*	1,332	649	49	681	51	2	0	0	—
Cox's Orange × Edward VII	323	27	8	191	59	57	18	48	15
Cox's Orange × Madame Rouge	2,083	160	8	1,781	85	126	6	16	1
Cox's Orange × seedling (Crawley Beauty × Cox's Orange)	614	106	17	463	75	43	7	2	1
Cox's Orange × Cravert Rouge	2,256	297	13	1,673	74	278	12	8	1
Cox's Orange × Crawley Beauty	2,710	780	29	1,850	68	75	3	5	0
Cox's Orange × Médaille d'Or	1,570	229	15	1,230	78	104	7	7	0
Cox's Orange × Blanc Dur	2,002	1,195	60	792	39	13	1	2	0
Cox's Orange × La Nationale	1,685	248	15	1,297	77	121	7	19	1
Cox's Orange × Canada Blanc	2,182	43	2	1,562	72	505	23	72	3
Cox's Orange × Court Pendu Plat	2,120	390	18	948	45	558	26	224	11
Cox's Orange × Camuzat	1,286	1	0	859	67	361	28	65	5
Cox's Orange × Fleuretard	1,182	105	9	874	74	139	12	64	5
Court Pendu Plat × Edward VII	97	1	1	66	68	21	22	9	9
Crawley Beauty × Malling XVI	465	29	6	260	56	140	30	36	8

* The pollen parents are arranged in order of increasing lateness in time of leaf break.

A record of the time at which these seedlings came into leaf was made from their second year onwards, Cox's Orange Pippin, Crawley Beauty and Médaille d'Or being used as standards of comparison (Table III).

Except among the selfs of the late flowering varieties, Crawley Beauty, Court Pendu Plat and Camuzat, seedlings leafing out very late in the spring did not occur with great frequency. In the hybrids they were most numerous in the crosses between Cox's Orange, Court Pendu Plat and Edward VII. In general, there is a greater proportion of late leafing seedlings in families where the pollen parent is late leafing. The only notable exception is Cox's Orange × Edward VII where neither of the parents is outstandingly late leafing and the proportion of late leafing seedlings is greater than in any other cross. The results suggest polygenic control of season, but this does not preclude the possibility that one or more major genes may form part of the gene-complex.

Time of defoliation in the autumn

Records on autumn defoliation made on more than 23,000 seedlings over the period 1954-57 have not revealed any significant relationship between this character and the time of bud burst in the spring. Camuzat selfed gave about 89 per cent of seedlings late or very late in defoliating and rather more than half of the F_1 of Crawley Beauty × Malling XVI were late ; in the other families the proportions ranged from 33 to 2 per cent.

The incidence of disease

Outbreaks of Apple Mildew in their first year after planting out have been recorded on these seedling families. Dilute fungicides were applied to achieve partial control of Apple Mildew, but despite this about 40 per cent of all seedlings were affected in 1954 and 70 per cent in 1957 (Table IV). There are few clear indications of the inheritance of varietal resistance among the families but since two of the crosses involving Cox's Orange showed 88 and 90 per cent Mildew, respectively, it seems unlikely that Cox's itself carries any dominant resistance genes.

In 1956, about 5 per cent out of almost 10,000 seedlings, in their first season, were affected with leaf lesions of Apple Scab. Cox's Orange selfed and the families Cox's Orange × Tydeman's Late Orange and Cox's Orange × Médaille d'Or were particularly heavily infected. In 1957 about one-third

TABLE IV

INCIDENCE OF APPLE MILDEW AND APPLE SCAB IN FAMILIES OF SEEDLING APPLES : PERCENTAGES INFECTED

	Apple Mildew				Apple Scab	
	1954	1955	1956	1957	1956	1957
Camuzat selfed	—	—	0	—	4	—
Court Pendu Plat selfed	11	0	1	66	0	8
Cox's Orange Pippin selfed	36	17	15	71	18	29
Cravert Rouge selfed	—	—	—	72	—	12
Crawley Beauty selfed	0	3	3	68	1	19
La Nationale selfed	—	—	—	80	—	49
Médaille d'Or selfed	—	—	—	72	—	38
Cox's Orange × Blanc Dur	49	6	4	—	0	—
Cox's Orange × Camuzat	—	—	1	84	5	39
Cox's Orange × Canada Blanc	—	—	1	0	4	—
Cox's Orange × Court Pendu Plat	67	1	2	—	3	—
Cox's Orange × Cravert Rouge	70	5	—	—	—	—
Cox's Orange × Crawley Beauty	40	4	—	—	—	—
Cox's Orange × Edward VII	—	—	2	77	1	25
Cox's Orange × Fleuretard	—	—	2	59	5	21
Cox's Orange × La Nationale	—	—	1	73	4	29
Cox's Orange × Madame Rouge	—	2	3	—	4	—
Cox's Orange × *Malus* species (unnamed)	—	—	—	29	—	36
Cox's Orange × Médaille d'Or	—	—	6	52	14	36
Cox's Orange × seedling (Crawley Beauty × Cox's Orange)	—	—	10	88	5	29
Cox's Orange × seedling (D'Arcy Spice, open pollinated)	—	—	—	90	—	32
Cox's Orange × Spätblühender	—	—	—	46	—	5
Cox's Orange × Tydeman's Late Orange	—	—	8	78	10	50
Court Pendu Plat × Edward VII	—	—	—	82	—	9
Crawley Beauty × Edward VII	—	—	—	75	—	24
Crawley Beauty × Malling XVI	14	—	—	—	—	—

of all the seedlings were affected. Cox's Orange × Tydeman's Late Orange had the largest proportion of scabbed seedlings and Cox's Orange × Spätblühender the least. Seedlings of Court Pendu Plat, both when selfed and when crossed with Edward VII, were relatively little attacked.

Selection for fruiting trials

Only those seedlings showing a pronounced late leafing habit and completely free from Apple Mildew and Apple Scab are being selected for carrying on into the flowering and fruiting stage. They are grown upon their own roots in cordon rows, trained to wires, and a duplicate tree of each on a dwarfing and precocious rootstock is raised to provide fruits quickly. Out of 24,498 seedlings dealt with so far, only 1,288 or about 5 per cent, have been selected.

Because of their particular interest, all the seedlings of Cox's Orange selfed are being grown on for the present although only two seedlings out of about 200 so far recorded have been late in season of leaf break and a considerable proportion have proved susceptible to Apple Mildew.

The oldest seedlings are only four years old and the first flowers cannot be expected for several seasons yet. They are being closely watched to check that they retain their late leafing character and their resistance to disease with the passing of the juvenile phase.

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Summary

Breeding work, initiated in 1950 to produce late flowering apple varieties of commercial value, is described. Seedlings from a large number of crosses, mostly between Cox's Orange and late flowering

varieties, as well as self-pollinations, have been classified and selected on their time of leaf break in the spring, a character shown to be correlated with season of flowering. Those late leafers showing resistance to Apple Mildew and Apple Scab have been retained for further observation and selection on flower and fruit characters.

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AN EARLY SPORT OF A RED CURRANT

By R. L. KNIGHT and ELIZABETH KEEP

In 1954, it was noticed that a branch on one of the bushes of a red currant seedling, B56, bred by H. M. Tydeman at East Malling, was markedly earlier in leafing out, flowering and fruiting than the rest of the bush. During the following three years, this branch maintained its earliness relative to the rest of the bush, and to other plants of the same clone, the difference being exceptionally well marked in 1957, when the sport was in full bloom on 14th March, at which time the normal branches and the rest of the clone were just breaking dormancy. The normal plants did not reach full bloom until 18th April. The difference in season of fruiting was not as wide, being about 10 days in 1957, because fruit from the early flowers takes longer to ripen owing to colder weather.

In 1957, examination of 100 fruits of each type gave the following data :

Mean weight of fruit (g.)		Mean seeds per fruit	
Normal	Early	Normal	Early
0·533	0·395	7·9	4·4

Counts of all strigs on a single branch of each type showed the normal to have an average of 13·6 fruits per strig compared with 8·3 for the sport. It seems unlikely that these differences in fruit characters are direct genic effects ; they are more probably the result of poorer pollination conditions early in the season due to lack of insects, low temperatures, and absence of any other open red currant flowers to provide pollen for the early sport.

Softwood cuttings from both the normal branches and the sport were propagated in 1956, and these showed the same relative differences in time of flowering and leafing out in the following season.

In the 1957 season, the earliness of the sport far exceeded that of any other red currant variety in a fairly comprehensive collection at East Malling. Such a degree of earliness would probably be of value in more southerly areas less subject to frost. Since the early branch must have arisen as a bud sport it is likely to have been caused by a single gene mutation to a dominant allele, which could thus readily be used for breeding purposes. The degree of fertility of this sport makes structural change in the chromosome complement a less likely explanation than point mutation. That changes of this degree can occur in *Ribes* is already known from the behaviour of Daniels' September black currant. This variety, which arose as a sport of Baldwin(2), is about ten days later than its parent. Moreover, branches and sometimes whole plants of this variety often revert to the ripening season of Baldwin(1). This again suggests a single gene change, followed by a back mutation. Tydeman's(3) finding that season of leafing out in black currants is controlled by two dominant additive genes is further evidence of major gene control of season in *Ribes*.

Summary

An early sport of a red currant is described and its probable genetic control is discussed.

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CYTOLOGICAL NOTES

By ELIZABETH KEEP

Some of the cytological data that have accumulated at East Malling as an adjunct to the fruit breeding programme are briefly presented in this paper.

Top fruit

Apples

Laxton's Superb sport.—In 1955, it was reported that several outstandingly vigorous trees of Laxton's Superb on M.II in a trial plot were cropping poorly and irregularly, the fruit being misshapen and larger than normal (Fig. 1*a*). The abnormal trees showed distinctive vegetative characters also, most notably a more spreading growth habit due to wider angled branching (Fig. 1*b*). These abnormal trees must presumably all have been propagated from one original sport. Average petiole lengths, length/breadth ratios of the leaves, and average number of seeds per fruit were determined for normal and abnormal trees (Table I). Average petiole lengths and length/breadth ratios were found by measuring in June all mature leaves on 10 current year's shoots, excluding the crowded leaves at the base. This gave a total of 97 and 98 leaves respectively for trees 6/15 and 6/17 (normal), and 96 leaves for tree 6/16 (sport). The average number of apparently viable seeds per fruit was determined on a total of 98 fruits each from two trees.

TABLE I

LEAF MEASUREMENTS AND SEED COUNTS IN NORMAL AND SPORT TREES OF LAXTON'S SUPERB

Tree	Type	Average leaf length/breadth	Average petiole length (mm.)	Average number seeds per fruit
6/15	normal	1·87	26·57	—
6/17	normal	1·83	26·21	5·24
6/16	sport	1·59	21·91	4·10

The data in Table I show that the sport is distinguished by its relatively broader leaves, shorter petioles and lower seed set. Since these characteristics, together with a spreading growth habit and large, coarse fruit, are typical of tetraploid apple sports as described in the literature(3, 8, 10), a cytological examination was made to see if this sport, also, was tetraploid.

Tips of actively growing shoots of tree 6/15 (normal) and of 6/16 (sport) were embedded in wax in June 1956, sectioned at 7μ and stained by a chromic acid modification of the crystal violet method (13). The meristems of 6/15 were found to be entirely diploid (2n=34) while those of 6/16 were periclinal chimaeras with a diploid epidermis surrounding a core of tetraploid (2n=68) tissue. The tetraploid cells of the sport were markedly larger than the corresponding diploid cells of the normal tree (Fig. 1*c*).

Large fruited tetraploid apple sports are by no means rare(3, 4, 8, 9)—indeed, two have been discovered at East Malling within five years. As the crop of such trees is usually lower than that of the diploid parent, and the fruit of poorer appearance and keeping quality, they are rarely commercially desirable, so that their early recognition is advisable. Apart from the size and coarseness of the fruit, the most constant characteristic of tetraploid sports is their spreading habit, often accompanied by the leaf characters described above.

Prunus

Chromosome counts.—Chromosome counts for some plum and cherry rootstocks and *Prunus* spp. are given in Table II. All counts were made on root tips embedded in wax, sectioned and stained in crystal violet.

TABLE II

CHROMOSOME COUNTS OF PLUM AND CHERRY ROOTSTOCKS AND OF *PRUNUS* SPP.

	2n
F12/1	16
Common Mussel, E5	48
Damas C, E17/3	48
Myrobalan B, E10/2	16
Prunus canescens, G254	16
P. glandulosa albo-plena, G256	16
P. japonica Nakaii, G257	16
P. pseudo-cerasus, G253	32
P. spontanea, G255	16
P. tenella	16

Soft fruits

Rubus

Formation of unreduced diploid gametes in interspecies hybrids

1. (*R. occidentalis* × *R. idaeus*) × *R. idaeus*.—The following backcrosses of purple-cane hybrids (*R. occidentalis* × *R. idaeus*) to red raspberry (*R. idaeus*) were grown in 1955:

Family number	Parentage	Number of plants
139	75/31 × Lloyd George (L435)	139
140	53/9 × Lloyd George (L435)	80
141	75/31 × 78/106	30

75/31 = Cumberland (*R. occidentalis*) × 64/53 (*R. idaeus*).
53/9 = Naples (*R. occidentalis*) × Enterprise (*R. idaeus*).
78/106 = Norfolk Giant (*R. idaeus*), open pollinated.

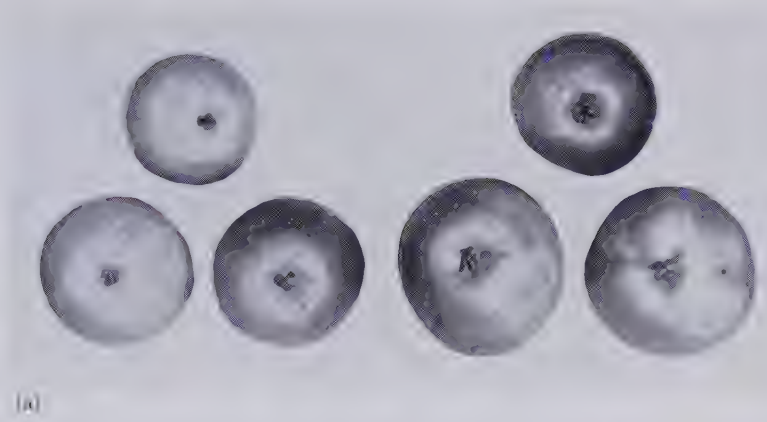
Of the 139 plants in Family 139, 87 were extremely vigorous, being distinguished from the rest of the family and from Families 140 and 141 by this and by their very large, coarse leaves with thick petioles. These plants were all more or less sterile, the rest of the family and nearly all seedlings in Families 140 and 141 being fully fertile. Examination of root tips from tip layers of six of the sterile seedlings in Family 139 showed them to be triploid (2n=21), a fertile control plant being diploid (2n=14). Thus Family 139 contained nearly 63 per cent of such types, whereas only one plant in Family 140 and none in 141 showed the vigour, leaf type and sterility characteristic of triploids. It is evident that a high proportion of diploid gametes functioned in the cross of 75/31 × Lloyd George. Presumably the unreduced gametes were from the female parent, 75/31, since Family 140, of which Lloyd George was the male parent also, contained only one possible triploid. Red raspberries normally produce about one triploid in 400 seedlings(1) and from numerous crosses and selfs of Lloyd George it is evident that this variety does not behave differently. The absence of triploids in Family 141 suggests that the comparative effectiveness of the reduced and unreduced ovules in 75/31 is influenced by the particular male parent used. Such behaviour is comparable with that shown by polyploid facultative apomicts in *Rubus*, which show a variation in the degree to which apomixis is developed according to the species used as male in cross pollinations(7). Apomixis has not yet been reported in diploid species and hybrids in *Rubus*, but the production of a high proportion of unreduced ovules by this purple-cane hybrid indicates a potential ability to reproduce by this means.

2. (*R. palmatus* × *R. idaeus*) × *R. idaeus*.—In 1952, L308/1, a diploid seedling of the early flowering species *R. palmatus*, was pollinated with Lloyd George. The F_1 plants were almost entirely sterile and chromosome counts on root tips of a sample of three of them showed all to be diploid (2n=14). One of these seedlings (96/2), backcrossed as female to Lloyd George, gave four plants, all of which were considerably more fertile than 96/2. Cytological examination of one of these backcross seedlings showed it to be triploid. The other three were so similar that there can be no doubt that they also were triploids. Bulk open pollinated seed from Family 96 was saved in the same year: three out of a sample of four of the resultant seedlings also proved to be triploid. Undoubtedly all these triploid plants arose from the fertilization of unreduced ovules by haploid red raspberry pollen.

Chromosome counts.—Chromosome counts were made on root tips of the following *Rubus* species:

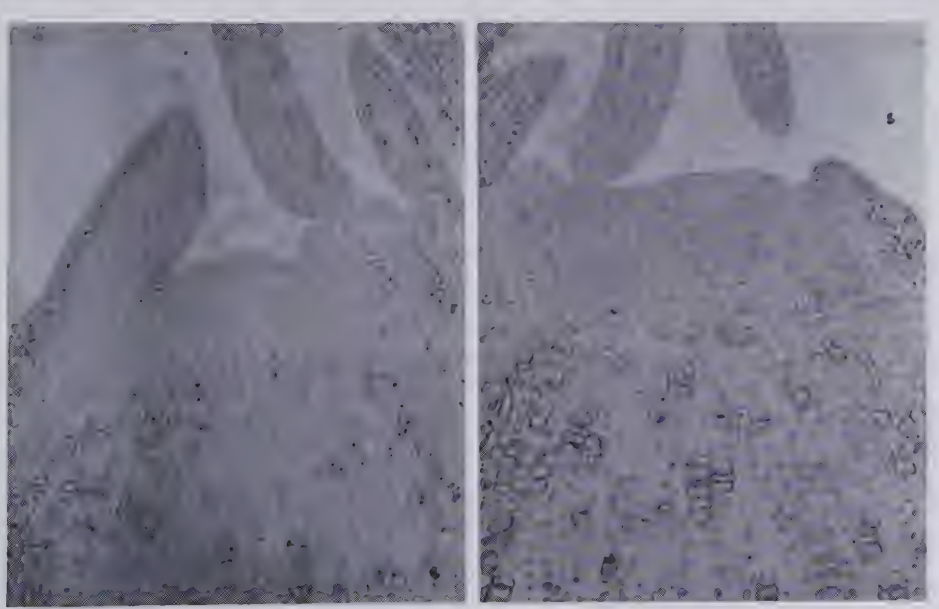
	2n
**R. crataegifolius* (L535)	14
R. hawaiiensis (L574)	14
R. henryi bambusarum (L457)	28
R. henryi bambusarum (L583)	28
R. tricolor (L464)	28

* Count made by Mr. R. A. Whitehead.



(a)

(b)



(c)

Fig. 1

Laxton's Superb, normal (left), sport (right).

(a) Fruit
(b) Ten-year-old trees
(c) Median longitudinal section of shoot tip (×148)

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Ribes

Genome homology between black currant, red currant and gooseberry.—Some disagreement among taxonomists as to the systematic classification of the three main economic groups, gooseberries, red currants and black currants is apparent. Janczewski(11) includes each group in a separate sub-genus of *Ribes*, while Berger(2) places gooseberries in the genus *Grossularia*, retaining red and black currants in separate sub-genera of *Ribes*. Rehder(15) includes both red and black currants in different sections of the sub-genus *Ribesia* while gooseberries are included in a section of the sub-genus *Grossularia*. Thus, Rehder and Berger regard red and black currants as being more closely related to each other than to gooseberries, while Janczewski gives all three groups equal status.

The relative ease of hybridization between species and the fertility and behaviour of the chromosomes at meiosis of the resultant hybrids are pointers to the phylogenetic relationships of the species. Hybrids of both black currant × gooseberry and of black currant × red currant are readily obtained and the hybrids are almost completely sterile. Although Kuzmin(12) reports a successful cross of the red currant variety Kazyrgan × gooseberry, several attempts to cross red currant with gooseberry at East Malling have produced only two seeds, neither of which germinated. Meurman(14) reported that meoisis in pollen mother cells of *R. culverwellii* MacFarl. (*R. nigrum* × *R. grossularia*) was extremely irregular, from 0-16 univalents occurring at metaphase I and only 3 per cent of cells showing the possible maximum of eight bivalents. No data appear to have been published on chromosome behaviour in red × black currant hybrids.

To investigate the possibility of gene transference from group to group in *Ribes*, meiosis has been studied in a range of inter-species hybrids, brief data for three of which are presented (Table III). *R. culverwellii* is included because, although Meurman(14) described meiosis in this inter-group hybrid, he gave no information on chiasmata frequency. *R. longeracemosum* Franch., the male parent of B22, is included by systematists in the red currant section, but is not one of the species from which the cultivated red currant varieties are derived. The invariable fertility of intra-section species hybrids in *Ribes*, and the almost completely regular chromosome behaviour of five such hybrids reported by Meurman(14) suggests that chromosome homology between species from the same section is very close, so that meiotic behaviour in B22 might be expected to be very similar to that of hybrids between black currant and commercial red currant. Data for two intra-section hybrids, *R. koehneanum* Jancz. and *R. saundersii* Jancz., and for the varieties Baldwin and Broom Girl, the parents of Hb6/30, have been included in Table III for comparison.

TABLE III

MEIOSIS IN POLLEN MOTHER CELLS OF *RIBES* SPECIES AND INTERSPECIFIC HYBRIDS

Type	Parentage	Average no. chiasmata per cell	Average no. bivalents per cell	Group
R. culverwellii	*R. nigrum* × *R. grossularia*	4·1 (71)	3·8	R5 × H1
Hb 6/30	*R. nigrum* × *R. grossularia*	4·2 (73)	3·8	R5 × H1
B22	*R. nigrum* × *R. longeracemosum*	5·3 (98)	4·5	R5 × R7
R. koehneanum	*R. multiflorum* × *R. sativum*	10·3 (33)	8·0	R7 × R7
*R. saundersii**	*R. nigrum* × *R. hudsonianum*	10·9 (24)	7·7	R5 × R5
Baldwin	*R. nigrum*	12·0 (69)	8·0	R5
Broom Girl	*R. grossularia*	13·1 (24)	8·0	H_1

Numbers in brackets = number of cells examined.
R5 = black currant group; R7 = red currant group; H1 = gooseberry group.
* The identity of this plant has not yet been confirmed.

The chiasmata frequency of a hybrid is a measure of the chromosome homology of its parents so that the data in Table III demonstrate a closer relationship between *R. nigrum* (Baldwin) and *R. longeracemosum* than between *R. nigrum* and *R. grossularia*. The two fertile intra-section hybrids, *R. koehneanum* (red currant section) and *R. saundersii* (black currant section), again show very similar chiasmata frequencies, considerably higher than those of the two sterile inter-group hybrids. The two species, *R. nigrum* and *R. grossularia*, give the highest chiasmata frequencies, as expected.

Although too few individuals have been examined as yet to draw firm conclusions about group relationships in *Ribes*, the data in Table III suggest that the red and black currant groups bear a closer relationship to one another than the black currant group does to the gooseberry. The ease with which hybrids of black currant × gooseberry are formed and the considerable amount of chromosome pairing they show suggest that both types are correctly included in the one genus. So far, no

red currant × gooseberry hybrids have been available for study, but the failure of attempts to breed such hybrids suggests a greater degree of differentiation between these two groups than that between the black currant group and the gooseberry.

Summary

A cytochimaeral sport of Laxton's Superb apple is described and the distinguishing characteristics of such sports enumerated. The occurrence of unreduced diploid gametes in two *Rubus* species hybrids is recorded and discussed. Data on pollen mother cell meiosis in *Ribes* hybrids are tabulated and their significance with regard to genome homology between black currant, red currant and gooseberry is discussed. Chromosome numbers of some plum and cherry rootstocks, of five *Prunus* species and of four *Rubus* species are listed.

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WEATHER CONDITIONS DURING 1957

By G. F. TROWELL

East Malling Research Station

Exceptionally mild conditions were experienced throughout the first three months of the year, resulting in a very early spring, once again a dry one, with cold northeasterly winds. A serious frost in May, plus low day and night temperatures, high temperatures in June, and a dry autumn, made up the many outstanding features of 1957 ; many records were broken, appropriately during the Geophysical Year.

Mean air temperatures were above average, except during May, August, September and December ; in January, February and March they were the highest for this period since records began in August 1914, January and February both being 3·2° F., while March was 6·3° F. above average, the highest mean air temperature recorded in March at East Malling. Throughout the year the mean air temperature was 1·4° F. above the 30-year average. Mean maximum screen temperatures were generally above average, although the summer months of May, August and September were below. The highest screen temperature in 1957 was 92° F., recorded on 29th and 30th June. This is the highest screen temperature in June since records began at East Malling, equalling the highest screen temperature at this Station, 92° F. recorded in July 1921 (the previous highest screen temperature in June was 90° F. in 1947). The highest maximum temperature for July since 1948 was 89° F., recorded on 6th, but the highest temperature reached in September was only 70° F., the lowest since 1931. Mean minimum screen temperatures were mostly above average, only May, June, September and December being below. The mean minimum temperature for March was the highest since 1943, while May on the other hand was the lowest since 1949. Temperatures during the first three months were not seasonable, the lowest air temperature for this period was only 27° F., the highest since 1930. The lowest temperature of the year did not occur until December, when 18° F. was recorded, the lowest temperature in December since 1948.

Rainfall during the year totalled 24·41 in., 2·32 in. below the 35-year average ; the distribution was again unusual, only February, July and September being above average. Although January was 0·74 in. below average, it had the highest number of days (21) on which rain fell in any month, with traces of rain on 5 other occasions. February was the wettest month with 3·51 in., rain being recorded on 19 days. Rainfall in March, April, and May is important from the agriculturalist's point of view, and for the past six years has been below average ; in 1957 it was again deficient, total rainfall for the period being 2·61 in. below average. A dry April created yet another record for 1957, as the driest since records began in 1914, only 0·15 in. of rain falling on six occasions. The previous driest April was in 1955 when 0·20 in. were recorded, and prior to this was in 1954, with 0·38 in. July was a wet month, 3·25 in. of rain being recorded on 16 days, of which 1·19 in. fell on one day, mostly during a thunderstorm ; July 1956 was the wettest since records began. Rain fell on 19 days during September, but the first 15 days in October produced no recordable rain ; this was the longest dry period of the year, while the wettest was between 18th and 25th December. The heaviest day's rainfall was on 3rd November when 1·28 in. were recorded. Rain fell on 163 days during 1957.

Sunshine during the year amounted to 1,598·1 hours, 35 hours above the 25-year average, and 129 hours above the 1956 total. June was the sunniest month with 275·5 hours sunshine, and of this 15·2 hours were recorded on 28th, the sunniest day of the year. The total sunshine for July, August and September was below average, and although July and August had sunshine on every day, the deficit was 74 hours. No sunshine was recorded on 62 days during the year.

Ground frosts were fewer than in the past (70 compared with 100 in 1956, and 95 in 1955), the largest number occurring in December. The number of ground frosts in March was less than usual, 7 compared with 15 in 1956, and 23 in 1955. May on the other hand, had the highest number since 1949 (Table 1). Frosts in May caused damage to blossoms (e.g. strawberries, Fig. 1) and small fruitlets (plums, pears and apples), especially on 6th, when the screen minimum fell to 28° F. and the grass minimum to 22° F. This was the lowest frost in May since 1944, when a screen minimum of 24° F. and grass minimum of 20° F. were recorded on 8th, but blossoming in 1944 was later than in 1957, full bloom on Cox being on 1st May, as compared with 21st April this year (Fig. 1). A further and last frost was experienced on 31st May, when the screen temperature fell to 32° F. and the grass temperature to 29° F. The first autumn ground frost was on 30th September, and the first air frost on 20th October.

Spring was extremely early, Myrobalan B starting to flower on 10th February (Fig. 1), as compared with 22nd March last year, though that was later than usual. Myrobalan B last flowered as

Table I
SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1957

East Malling

Month	Temperature in Screen (°F.)					Number of Ground Frosts	Rainfall (in.)			Sunshine (hours)			Soil Temperatures (°F.)			
	Mean maximum	Mean minimum	Highest	Lowest	Mean		Total	Heaviest fall in a day	35 years' average	Total	Average per day	25 years' average	4 inches	8 inches	2 feet	4 feet
January	47·1	36·8	55	28	42·0	12	1·72	0·27	2·46	54·6	1·8	47	38·9	39·7	41·8	43·8
February	48·4	37·0	55	27	42·7	14	3·51	0·71	1·95	71·4	2·6	68	39·8	40·8	43·0	44·1
March	56·3	41·4	65	27	48·9	7	1·11	0·25	1·57	123·3	4·0	123	45·8	45·7	46·3	45·4
April	56·3	39·5	67	30	47·9	6	0·15	0·06	1·90	172·7	5·8	152	48·7	49·0	49·8	48·5
May	59·5	41·7	70	28	50·6	5	1·53	0·59	1·93	198·1	6·4	200	53·4	52·8	53·2	51·1
June	71·2	48·1	92	36	59·7	0	1·40	0·47	1·63	275·5	9·2	222	62·6	61·3	60·6	56·1
July	71·9	55·5	89	48	63·7	0	3·25	1·19	2·25	172·5	5·6	208	65·1	64·2	64·6	61·0
August	69·3	52·3	79	40	60·8	0	2·24	0·41	2·35	182·2	5·9	194	62·1	61·8	62·9	61·1
September	64·0	49·0	70	34	56·5	1	2·86	0·49	2·18	120·2	4·0	147	56·0	56·4	58·3	58·4
October	60·5	43·9	69	31	52·2	3	1·17	0·36	2·85	102·5	3·3	105	50·4	51·3	53·3	54·7
November	49·0	39·5	56	26	44·3	7	3·00	1·28	3·18	68·2	2·3	55	42·9	44·5	47·5	50·5
December	45·6	32·5	56	18	39·1	16	2·47	0·69	2·48	56·9	1·8	42	37·8	39·4	41·8	45·1
Totals						71	24·41		26·73	1,598·1		1,563				

Sub-Station, Newlands Farm, Throwley

															12 inches	
January	45·1	36·6	53	30	40·9	9	2·33	0·40		65·5	2·1		39·7	41·1	42·5	45·1
February	46·7	37·1	53	29	41·9	11	4·25	0·77		75·6	2·7		40·3	42·2	43·0	44·5
March	54·4	42·6	62	35	48·5	7	1·34	0·30		133·3	4·3		45·3	46·2	45·7	45·2
April	52·7	40·2	63	31	46·5	5	0·35	0·08		164·7	5·5		47·3	48·3	48·2	47·5
May	56·6	42·4	65	31	49·5	6	1·51	0·38		211·3	6·8		51·5	51·3	50·7	49·1
June	68·2	49·5	89	39	58·9	3	0·96	0·24		286·7	9·6		61·0	58·3	56·6	52·7
July	70·0	54·6	87	47	62·3	0	3·51	0·58		157·2	5·1		63·4	63·8	62·2	57·4
August	67·0	52·4	77	43	59·7	0	1·98	0·50		172·2	5·6		60·9	61·9	61·6	58·8
September	61·9	49·1	68	36	55·5	1	3·66	0·66		114·2	3·8		56·2	57·9	58·4	57·5
October	58·9	45·4	67	37	52·2	4	1·46	0·32		105·5	3·4		51·6	53·2	54·1	55·0
November	47·1	39·2	54	30	43·2	6	3·96	1·54		60·5	2·0		44·2	46·7	48·8	51·6
December	44·8	34·6	53	24	39·7	16	2·48	0·65		67·9	2·2		39·3	40·8	43·1	46·8
Totals						68	27·79			1,614·6						

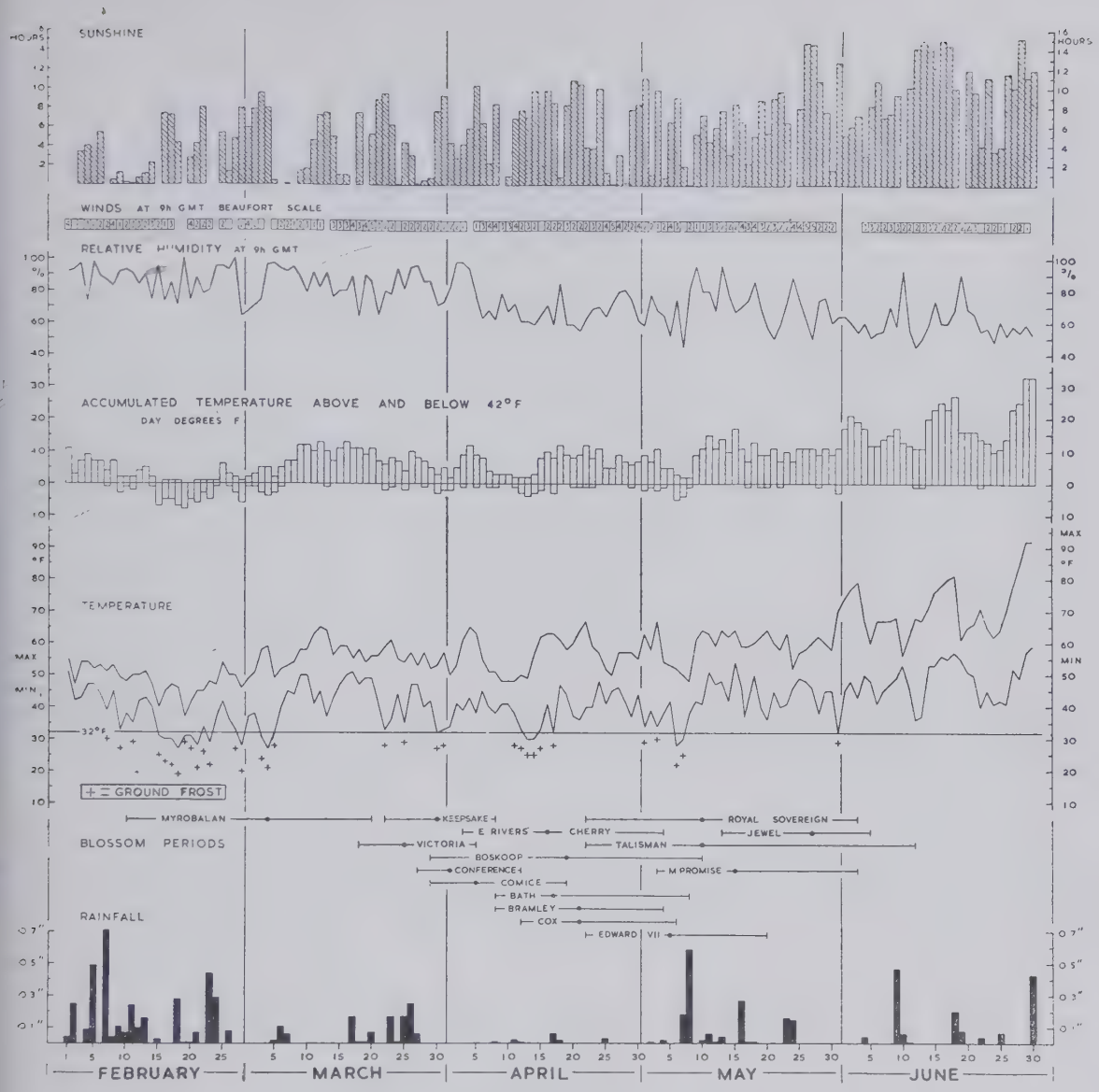

FIG. 1

Diagram showing the weather recorded during the blossoming season at East Malling Research Station in 1957

early as this in 1937. Similarly, full bloom on Cox was 19 days earlier this year than the average date for the past seven years.

Cold northeasterly winds persisted once again throughout much of April, and this year at the beginning and end of May. The total number of northeasterly winds recorded in 1957 was 74 ; 28 occurred in April and May, and these together with strong winds of ' Force ' 6 on 25th and 26th April, and on 25th, 26th and 27th May, made conditions for pollination poor on a large number of occasions when a majority of the blossoms were open (Fig. 1). Strong winds of ' Force ' 6 or over were recorded 31 times, the highest number since 1954. Gale force winds of over 40 m.p.h. were recorded only once on 4th November, when the highest gust was 49 m.p.h., but almost gale force was reached on 25th August. Winds from southwesterly directions were recorded on 122 occasions.

Thunderstorms were recorded 8 times over or in the neighbourhood of the Station, during May, June, July, and August, 5 occurring in July. Some brought heavy falls of rain, particularly that already mentioned on 14th July. Distant thunder was recorded on 4 other occasions.

The total amount of snow and sleet recorded over the past year was almost nil, occurring 8 times

during January, February and December, the ground being snow covered only once to a depth of $\frac{3}{4}$ in. on 19th February. Snow was not recorded at all during March, and only a very slight snow and sleet shower fell in December, on 15th.

Hail was recorded 5 times, all during the first half of the year. Fog was experienced on 30 occasions, the foggiest month being December.

Ground conditions during March were good for spring planting, being frozen only once, and then to less than 2 in. Dry ground persisted throughout April, wet ground being recorded only once, and these dry conditions continued into May. Conditions were good for early stock lifting and planting during October, dry ground being recorded 12 times, wet ground 15 times and soft muddy wet ground only on the remaining four days.

Newlands Farm, Throwley

Mean air and maximum temperatures were as in the past below those at East Malling, while the mean minima were about the same or slightly above. The highest temperature recorded was 89° F., on 30th June, and this was the highest temperature experienced since maximum records began in May 1951 ; the lowest temperature was 24° F., on 17th December.

Total rainfall at this sub-station was 3·39 in. below the provisional average, but 3·38 in. higher than at East Malling. February was the wettest month with 4·25 in. of rain on 19 days. As at East Malling, dry conditions were experienced at Throwley during April, 0·35 in. of rain falling on 8 occasions. The heaviest day's rainfall occurred on the same day as at East Malling, 1·54 in. on 3rd November. Rain fell on 177 days during the year.

As usual sunshine was again higher than at East Malling by 16·5 hours, but the difference was considerably less than in the past. The sunniest day was on 13th June, when 15·8 hours were recorded.

Ground frosts were fewer than usual, 68 compared with 104 in 1956, and 99 in 1955, and the lowest number since 1950. No air frosts were recorded in March, but 3 ground frosts were recorded in June, on 6th, 12th and 13th.

Gale force winds were experienced on 27 occasions. Thunderstorms and distant thunder were recorded 15 times. Snow and sleet fell 17 times during January, February, April, May and December. Hail was recorded 4 times, all during the first half of the year.

Acknowledgements

The author wishes to thank Mr. C. H. W. Slater for his assistance during the year. Mr. J. Cronk (by courtesy of Mr. T. Neame) was responsible for records on Newlands Farm, and his co-operation is gratefully acknowledged.

STATISTICS AND RECORDS

A COMPARISON OF METHODS OF MEASURING LEAF AREAS IN THE FIELD

By G. H. FREEMAN

In a previous paper(1) a grid was described for obtaining repeated measurements in the field of the areas of leaves without damaging them. The grid is designed to measure leaves elliptical or ovate in shape, and the reader is referred to that paper for a description of its construction. Various other methods have been used in the past for the measurement of leaf area, one technique being that of counting squares(5) ; this, though laborious, can be made very accurate and may be regarded as a standard method. It is the purpose of this paper to compare the efficiencies of the grid and square-counting methods and also to consider some effects of sampling.

In order to test the grid under a wide range of conditions two experiments were conducted on apple plants during the summer of 1956. The first was concerned with finding whether the personal errors in the use of the grid invalidated comparisons between different observers, and also with confirming the conclusions from the small-scale trials(1) that the grid did give accurate measurements. The purpose of the second experiment was to observe whether the changes in shape of leaves of different varieties during the growing season imparted any bias to the method. Although the first experiment had the comparison of methods of measurement as its sole purpose the second was mainly concerned with leaf development, the comparison of methods being of secondary importance.

Experiment 1

In this experiment the total leaf areas of two plants of each of four varieties were obtained four times at weekly intervals during May and June by eight observers. Each plant was measured each week by four observers, two using the grid as described above and two counting squares of 1 sq. cm. Each observer measured four plants per day and, during the four weeks of the experiment, measured each of the eight plants once by each of the two methods. Further, each observer used the same method for a whole day ; this was done to assess effects of fatigue, although it made impossible direct comparisons of the two methods on the same observer, day and plant. The observers worked in pairs, one adding* and recording the measurements made by the other, and the two taking it in turns to measure and record, as is commonly done in determining leaf areas. The varieties used were one-year-old M.IX and 3423 and two-year-old 3430 and Cox's Orange Pippin, these last two both being budded on 3430 ; the one-year-old plants were grown in pots in John Innes compost and the two-year-old in pots in water culture.

The requirement that each observer should use only one method on any one day complicated the design of the experiment. Formally, the experiment, the layout of which is shown in Table I, was a $\frac{1}{2}$-replicate of a $2 \times 4 \times 4 \times 8$ factorial ; for ease of design, however, the four weeks and varieties were regarded as 2×2 factorials, the eight observers as a $2 \times 2 \times 2$ factorial and the two plants of each variety allocated to two blocks. In any experiment with less than one complete replicate, not only do high order interactions have to be used to estimate the experimental error but certain comparisons are indistinguishable from each other ; these are termed aliases and it is desirable that the alias of a main effect or important small interaction shall not be another interaction of importance. Here, however, this was not always possible, and certain degrees of freedom in the main effects and two-factor interactions were aliases of each other. Where the effect corresponding to any of these degrees of freedom was large it was usually possible to decide which of the two conceivable causes was the more likely.

The results of the experiment related to the total leaf areas of the plants obtained by the two methods and the time taken to obtain them. As might be expected, there were differences in area between both varieties and weeks and a suggestion that the rates of growth of the varieties were not the same ; there were, however, no interactions between varieties or weeks on the one hand and observers or methods on the other. It also appeared that the measurements made by the various recorders were similar by either method ; on the whole, however, the grid gave slightly higher areas than the square-counting. When the experimental error was partitioned into that due to differences

* The addition can be done in the field by a small hand-adder and it is found that this can be used at least as fast as leaf areas can be measured ; thus only the total leaf area of the plant is recorded.

TABLE I

LAY-OUT OF EXPERIMENT 1

	M.IX				3423				3430/3430				Cox/3430			
	Plant 1		Plant 2		Plant 1		Plant 2		Plant 1		Plant 2		Plant 1		Plant 2	
	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.	Sq.	Gr.
Week 1	1 3	5 7	2 4	6 8	2 4	6 8	1 3	5 7	1 3	5 7	2 4	6 8	2 4	6 8	1 3	5 7
2	5 7	1 3	6 8	2 4	6 8	2 4	5 7	1 3	5 7	1 3	6 8	2 4	6 8	2 4	5 7	1 3
3	6 8	2 4	5 7	1 3	5 7	1 3	6 8	2 4	6 8	2 4	5 7	1 3	5 7	1 3	6 8	2 4
4	2 4	6 8	1 3	5 7	1 3	5 7	2 4	6 8	2 4	6 8	1 3	5 7	1 3	5 7	2 4	6 8

Sq. = Square-counting. Gr. = Grid measurement.

Observers numbered from 1 to 8, pairs working together being 1, 2 ; 3, 4 ; 5, 6 ; 7, 8. The numbers shown in the body of the Table are those of observers doing the measuring, the other one of the pair recording the observations ; for example, a plant measured by observer 1 would be recorded by observer 2, and vice versa.

It is a necessary consequence of the design that in any one week the following pairs of observers should measure the same plant by the same method : 1 and 3, 2 and 4, 5 and 7, 6 and 8.

between the grid and the square-count and that due to other causes, the former was negligible, amounting to only 3·4 per cent of the latter, a result suggesting that errors due to the use of the grid rather than the square-count can be ignored in practice.

The time taken varied with the observers, it so happening that the three slowest were three of the four who used the square-count in the first and fourth weeks and the grid in the second and third ; thus either method appeared slower when used by these people. In the fourth week, however, counting squares took an average of 15 min. per plant longer than using the grid, a difference too great to be attributable to observers. Time taken was regressed on leaf area, and this analysis showed that while, for small plants, it did not matter which method was used, for large plants the square-count took much longer, the regression coefficient here being more than three times that for the grid.

Experiment 2

Throughout the entire season leaf areas were measured at weekly intervals on particular leaves of three plants of each of ten varieties by means of the grid and square-count. The cross-product of length and breadth was also found, as the ratio of cross-product to area gives an indication of leaf shape. The plants used were all one year old and growing in pots in John Innes compost, the varieties being : M.IX, 3423, MM.109, Crab C, M.IV, M.XXV, M.XVI, MM.105, 3428, 3438. Although the aim, as stated above, was to measure three plants of each variety one plant of each of the varieties Crab C, M.XXV and M.XVI died early in the season and so most of the results below are based on 27 plants only. The leaves measured on each plant were one on the old wood, and, at three-weekly intervals, the youngest measurable leaf on the leading growing shoot, providing, over the season, an average of seven leaves per plant. Two observers made these measurements each week, experience showing that it was most satisfactory to take grid readings and cross-products for each leaf on all plants and then to start again and count squares, thus eliminating possible bias due to anyone remembering the area previously obtained for a particular leaf. The observers each measured three plants in succession and then recorded for three plants, changing sets of plants each week ; in any one week each person measured the leaves on the same plants by all methods. The observers were two who had taken part in Experiment 1, being replaced by one of two others when they were not available.

The results were examined from various aspects. Summing all the measurements for a week gave no differences between the grid and square-counting methods with either observer. Furthermore, the two methods gave the same result whatever the position of the leaf on the plant or the variety of plant. Comparisons of square-counting and cross-product showed that the shape of the leaves did not alter markedly with leaf position except that the leaf on the old wood was shorter for a given area than were those on the growing shoot.

The most stringent test of the grid, however, was a comparison for each observer and each week, 44 combinations in all, of the different values obtained on the same leaf by the grid and square-counting. The differences (t) of the values (grid minus square-count), expressed as ratios of their standard errors, ranged from 0·960 to −0·793, none of which approaches even the 20 per cent level of significance ; 32 of the values of t were positive and 12 negative, the value obtained from the weighted mean being 0·833, again far from the level required for significance. Within these 44 sets of values there were wide fluctuations in the variation, these not being associated solely with observers

or weeks but being most probably influenced by a few leaves, usually mis-shapen, that were consistently bigger according to one method of measurement than the other. For an individual leaf the coefficient of variation of the difference between grid and square-count, based on the mean value obtained by square-counting, was 14 per cent ; hence, for a sample of n leaves the coefficient of variation of the mean would be $14/\sqrt{n}$ per cent. Thus, since there were no consistent differences between the methods due to individual plants, leaf positions or observers, the extra error imparted by the use of the grid on even a small plant would be negligible.

Effects of sampling

It was apparent from the two experiments described above that, for most practical purposes, the grid could be taken as giving accurate measurements of the area of individual leaves. However, when large numbers of plants, even those only one or two years old, are to be measured on any one occasion it is impracticable to measure every leaf on a plant, and some form of sampling is then necessary. The above formula for the coefficient of variation suggested that about 60 leaves per plant should be measured, it being essential that the fraction of the plant to be taken should be assessed accurately. This method was found to give reasonably good results, but in order to confirm its reliability a further experiment on sampling was undertaken in 1957.

In this experiment six observers working in pairs measured 40 plants in a day with the grid, each person measuring 20 plants and recording for the other observer of the pair on the other 20 plants. The number of plants was chosen as that representing a normal day's work, so that it was neither possible for those taking part to use excessive care nor necessary for them to hurry unduly. The plants were then defoliated and the leaves counted, the areas being then determined by the photo-electric method described by Maggs(2). The results of the experiment showed that the average ratio of the leaf areas measured by the grid to those obtained from the photometer was 99·9 per cent, means for individual observers varying from 85·7 to 125·0 per cent. A check by complete measurement of some small plants and sampling of others without measurement broadly confirmed the impression that such errors as were present were due to sampling rather than measurement, though one person's measurements averaged about 10 per cent low.

The number of leaves measured varied with the observer and the plant, but it was found that the accuracy of the assessment of the total leaf area of the plant did not increase if more than 60 leaves were taken. The method of selection of the leaves also varied, it being easier at some times to take every nth leaf, and at others every leaf on certain shoots or clusters ; on some plants a combination of the two methods proved most satisfactory. The results imply that the best method is that found easiest by the person doing it, provided that the fraction of the total leaves taken is what it is stated to be.

The sampling experiment, together with the checks, confirmed the impression obtained from the 1956 experiments of the similarity of the results of the same observers on different plants, although three of those taking part in 1957 had not done so in 1956. Experience with these observers and others suggests that anyone can be rapidly trained in the use of the grid, a short demonstration together with about an hour's practice sufficing to ensure the required standard of accuracy. Some people appear to be naturally better at judging the fraction of a plant represented by a certain number of leaves, but here again practice leads to improvement.

Discussion

As the varieties used during the course of these experiments had leaves of widely different shapes and sizes there is reason to suppose that the results may hold for any apple variety at any time during the season. Thus, the grid can be safely recommended for use in the measurement of leaf areas of whole plants, and indeed is already being used at East Malling in connexion with widely different problems. The consistent discrepancies between the areas obtained by grid and square-counting on occasional leaves, even though most of these leaves were abnormal in some way, make it advisable to proceed with greater caution in studies of the development of individual leaves ; even here, however, the grid is probably satisfactory for most experimental purposes.

Although based only on apple, these recommendations may well apply to all plants whose leaves are a similar shape, i.e. not only ovate but narrowing rapidly at the tip ; approximation to an ellipse might also obtain for lanceolate leaves and for obovate leaves narrowing rapidly at the base. The necessary condition in each case is that areas inside the leaf and outside the ellipse, and vice versa, should compensate for each other. It would be possible to obtain areas by one direct reading for other leaves, e.g. some of those with shapes expressible mathematically(4) ; here, the condition is that the equation of the leaf should be such as to give an expression for the area in terms of easily determined quantities. For yet other leaves an empirical measurement of area might be found, not

expressible in simple mathematical terms but none the less holding closely in practice ; this has in fact been done for sugar beet leaves by Owen(3), who has constructed a grid giving very good estimates of area despite the lack of an accurate mathematical expression for the leaf shape. For all species, however, it would be as well to carry out checks on the method, on the lines of Experiments 1 and 2 here.

For approximately elliptical leaves experience with apple suggests that errors due to sampling, for any plant, outweigh those due to measurement. Thus, attention should always be paid to the reduction of such errors, in particular to the correct assessment of the fraction of the plant being measured. The general conclusion is that, when a direct measurement of leaf area is required on growing plants with leaves of this shape and when there is no indication of bias, the grid should be used in preference to other methods, being more rapid and no less accurate.

Summary

Various methods for obtaining the areas of elliptically shaped leaves in the field are compared. Experiments on apple plants are discussed which show that a direct-reading grid is more rapid and no less accurate than the method of counting squares and is not subject to bias due to different observers, varieties or ages of leaves. Consideration is also given to the reduction of errors in sampling whole plants, the most important point here being the correct assessment of the fraction of the leaves on the plant to be measured. The application of this grid, or others, to leaves of other species is also discussed.

Acknowledgements

My thanks are due to Mr. D. J. Avery, who shared the major part of the work of Experiment 2.

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Note added in proof.

Recent Russian work suggests that, at least on older trees, the ratio of the leaf area of a given variety to the area of its containing rectangle is practically constant. This is not borne out by the observation reported from Experiment 2 on p. 84 above.

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SAMPLING METHODS FOR THE MEASUREMENT OF EXTENSION GROWTH OF APPLE TREES*

By G. M. JOLLY and D. A. HOLLAND

The standard method of measuring annual extension growth(1) is easily applied to small apple trees, but the work involved tends to become excessive with large trees. An attempt has therefore been made to find reliable but less laborious methods of estimation. The findings may well be applicable to other tree species.

Methods considered

Four methods of estimation were tried. In the first, one primary branch of each tree was selected at random and the total extension growth on it measured. Covariance methods were then used to adjust these measurements for differences in branch girths measured before the application of experimental treatments. Results from several sets of data, however, usually showed a marked loss of accuracy and the method was abandoned.

The second method attempted was one of visual estimation. A number of independent observers were asked to assess the extension growth on each tree in a trial using categories 1 to 5. However, not only were the participants unanimous in their opinion that the task was an exceedingly difficult one, but the results showed the estimates to be incapable of detecting any but the coarsest of differences between trees. This method, therefore, was thought unlikely to repay further investigation.

More success was obtained with the third and fourth methods. Both are sampling methods in which the extension growth of the tree is estimated from measurements made on a part of the tree only. In the one the sample consists of a definite proportion of the shoots dispersed systematically over the whole of the tree, while in the other the growth on only one primary branch (*i.e.*, a branch arising direct from the trunk) selected at random is measured and then related to the whole tree by means of girth measurements made on all the primary branches. These two methods are illustrated in the present paper, and will be referred to as Systematic Shoot Sampling and Random Branch Sampling respectively.

In the past, extension growth has usually been measured in centimetres and this practice has been followed throughout this paper, although measurement in decimetres is generally accurate enough and saves time.

Source of data

Trials representing a wide range of tree size and form and four different growing seasons were used. Table I gives a brief description of these trials. Trials 1 and 3 comprised the same set of trees but at different ages, and the trees used in Trials 4 and 7 are included in Trials 8 and 9 respectively. In Trial 12 the trees on different rootstocks differed widely in size and while these trees were of an age when so sensitive a measurement as extension growth would seldom be needed they are included to provide an exacting test of the sampling methods as applied to trees on different rootstocks in general.

Some preliminary considerations

For each tree the sample data were first obtained, as described in subsequent sections of the paper, together with a record of the total extension growth on the tree. An estimate of growth was then made from the sample measurements by whichever of the two methods was being tried. On the assumption that the data were approximately log-normally distributed, the logarithmic transformation was used, and, henceforth, the logarithm of the actual growth of a tree will be denoted by x, and the logarithm of the estimate of growth derived from the sample denoted by y.

The relationship between x and y was assumed to be of the form

$$y = a + bx + \epsilon \qquad (1)$$

where a and b are constant for any one set of data, and ϵ is the random residual due to sampling error. The constancy of a and b is essential to the success of the sampling method, since, if either

* The term ' extension growth ' is here taken to mean any form of shoot growth, whether from terminal or lateral buds, as distinct from the secondary thickening of existing wood by cambial activity.

TABLE I

DESCRIPTION OF THE TRIALS USED IN THE INVESTIGATION

Trial	Number of trees	Variety	Rootstock	Age of trees (years)	Tree-form and method of pruning*	Type of trial
1	117	Worcester	M.VII	3	Regulated	Uniformity
2	115	Cox's	M.VII	3	Regulated	Uniformity
3	108	Worcester	M.VII	4	Regulated	Uniformity
4	19	Worcester	M.IV	4	O.C., E.S.	Pruning (only one treatment used)
5	19	Superb	M.IV	4	O.C., E.S.	Pruning (only one treatment used)
6	18	Superb	M.II	4	D.O.C., E.S. D.O.C., Renewal	Pruning
7	18	Cox's	M.II	4	D.O.C., E.S. D.O.C., Renewal	Pruning
8	60	Worcester	M.IV	6	O.C., E.S. D.O.C., E.S. Regulated	Pruning
9	60	Cox's	M.II	6	O.C., E.S. D.O.C., E.S. O.C. Renewal D.O.C. Renewal Regulated	Pruning
10	59	Superb	M.II	9	D.O.C., E.S.	Soil management
11	60	Fortune	M.II	9	D.O.C., E.S.	Soil management
12	26	Lane's	Mixed	34	O.C., E.S.	Rootstocks including: M.I, M.II, M.IV, M.VII, M.IX and M.XVI

* O.C. = open-centre ; D.O.C. = delayed open-centre ; E.S. = established spur.

were affected by the experimental treatments the treatment comparisons would be biased. For each set of data in which different treatments were represented this constancy was tested.

Provided the data satisfy equation (1), it is then clear that for comparative purposes the actual value, x, may be replaced by the estimate, y, irrespective of the value of a or b for the set of trees concerned. Only if a and b are near to 0 and 1 respectively will y provide a reliable estimate of the *absolute* extension growth of the tree, but this is irrelevant as long as only the relative growth under different treatments is of interest. The effect of random sampling errors in y, on the other hand, is to increase all standard errors and significant differences by a factor of $\frac{1}{r}$ where r is the correlation coefficient between x and y. Thus, the accuracy of the sampling method as compared with that of a complete growth record can be conveniently assessed by examining the values of r for each set of data. When data over more than one season are considered, the values of r will in general be greater than those relating to a single season ; for this reason each set of data used refers to growth in one season only.

Since high values of r are more likely to be obtained in plantations where the tree to tree variation is high, standard errors of x between trees, after eliminating treatment and block effects, are tabulated alongside r in the subsequent sections of the paper.

Systematic Shoot Sampling

This method consists of measuring every nth shoot, counting from the top of the tree in the same order in which all shoots are measured, and starting with the topmost shoot. As with the complete record any shoot measuring less than 5 cm. is ignored. The estimate, y, is then given by $y = \log$ (total length of all measured shoots) $+ \log n$; clearly, if n is the same for all trees, the term $\log n$ may be omitted.

A preliminary investigation in which samples were taken for different values of n suggested a marked falling off of the correlation coefficient with fewer than 20-25 measured shoots per tree. Accordingly, for each set of data a value of n was found from a rough estimate of the number of shoots on a tree so as to give an average of approximately 20-25 measured shoots per tree, n being usually rounded off to the nearest five (Table II).

Tests carried out in relation to equation (1) showed that different treatments did not affect a or b.

TABLE II

CORRELATION COEFFICIENTS, r_1 AND r_2, BETWEEN x, THE LOGARITHM OF THE ACTUAL AND y, THE LOGARITHM OF THE ESTIMATED EXTENSION GROWTH PER TREE

Trial	s Standard error of x	Systematic shoot sampling		Random branch sampling	
		n where every nth shoot is measured	r_1	Average number of branches per tree	r_2
1	0·10	—	—	3	0·84
2	0·13	2	0·96	3	0·86
3	0·11	3	0·93	—	—
4	0·18	—	—	3	0·95
5	0·19	—	—	3	0·97
6	0·17	—	—	4	0·84
7	0·14	—	—	4	0·89
8	0·19	5	0·95	—	—
9	0·09	10	0·88	—	—
10	0·27	15	0·97	3·5	0·88
11	0·18	10	0·96	4·5	0·77
12*	0·21	1 to 70	0·95	3·7	0·79

* The trees in Trial 12 were so variable in size that n was varied for individual trees, some requiring measurement of every shoot ($n=1$).

The fourth column of Table II gives the corresponding values, r_1, of the correlation coefficient between x and y, and the second column shows the tree to tree variability in terms of s, the standard error of x after eliminating block and treatment variations.

Most of the correlation coefficients are considerably higher than 0·9, indicating that in general there was little loss of accuracy due to the use of the sampling method. The lowest coefficient, 0·88, was found in Trial 9, but this might have been expected since the trees themselves are a relatively uniform set as the value of s indicates. For this trial the standard error of the estimate, y, was, in fact, $\frac{0\cdot09}{0\cdot88}=0\cdot10$.

Random Branch Sampling

The sampling unit for this method is a primary branch selected as described below. The extension growth for the whole tree is estimated by multiplying that on the sample branch by the ratio of the sum of all the primary-branch girths to that of the sample branch. Thus, if w is the growth on the selected branch of girth g, and G is the sum of all the primary-branch girths, y will be given by

$$y=\log \frac{w\,G}{g} \qquad (2)$$

The sample branch is selected at random from all the primary branches on the tree, excepting those that fall into one of the following categories.

(i) *Branches which are confined to either the top or bottom or the head of the tree.*—The reason for this restriction is that the shoots at the top of a tree were found to be larger, on the average, than those at the bottom, a fact previously recorded elsewhere(3). The growth on such a branch would not, therefore, be typical of the whole tree and if used as a sample would give an unsatisfactory estimate.

(ii) *Branches which have been severely cut back or damaged.*

(iii) *Branches which have bifurcated so close to the trunk as to make it impossible to measure a single girth.*

The above omissions apply only to the selection of the sample branch. Such branches will, of course, still be used for the calculation of G, measuring the separate girths of the secondary branches of those which have bifurcated close to the trunk.

With delayed open-centre trees, where the primary branches are not all formed in the same year and consequently arise over a considerable length of trunk, it is desirable to select one of the first tier of primary branches (*i.e.*, those of the first formative year) as a sample branch, and to use all of the first tier plus that part of the trunk above the topmost for the calculation of G. That is to say, the trunk above the first formed tier of branches is regarded as the highest primary branch so that all girths are taken on wood of the same age. In practice it was not always easy to recognize the branches belonging to the first tier, but a preliminary investigation carried out in Trials 10 and 11 involving

different combinations of branches showed that the effect of including, by mistake, a branch of a different age was not serious.

This method was applied to several trials and tests carried out in relation to equation (1) showed that neither a nor b were affected by treatments.

The resulting correlation coefficients, r_2, between x and y are given in Table II.

For the purpose of estimating fruit number the method has been criticized(2), but from the values of r_2 it can be seen that the method usually gives a moderately accurate estimate of extension growth. The lowest value of r_2, encountered in Trial 11, represents a loss in accuracy equivalent to an increase in the standard error of about 30 per cent. It is possible that relationships between branch girth and extension growth other than that implied by equation (2) might result in slightly higher correlation coefficients, but in the light of the present results the writers consider further investigation would be of little practical value.

Discussion

The relative merits of the sampling methods described are best discussed under the three headings (i) Systematic Shoot Sampling, (ii) Random Branch Sampling, and (iii) Measurement of all shoots on the tree.

(i) *Systematic Shoot Sampling.*—The method can be used on any form of tree whatever its condition, and where n averages 20-25 measured shoots per tree there is usually little loss of accuracy. If the trees vary considerably in size a smaller value of n may be desirable to avoid having too few measured shoots on the smaller trees.

A practical disadvantage is that the sample is dispersed over the whole of the tree which means that as much ladder moving is required as when every shoot is measured. Even so, time is saved by measuring only some of the shoots. A rough test, carried out on trees large enough to require ladders for the highest branches, indicated that to measure one shoot in ten took ten minutes, as against thirty minutes for the whole tree.

Occasionally, if the trees vary much in size, it may be convenient to use different values of n for different trees. This may happen where large block differences are present, when a value of n can be assigned to each block.

(ii) *Random Branch Sampling.*—This method may be used on any set of trees on which the necessary branch measurements can be made but will generally be less accurate than Systematic Shoot Sampling.

The advantage lies in reducing the amount of ladder work on large trees by restricting the sample to a single branch. The time spent by an experienced recorder in measuring the branch girths is small, so that the time taken for the sample as compared with the whole tree is approximately inversely proportional to the number of primary branches on the tree. On trees on which the branches all carry much extension growth, it would be possible to sub-sample the selected branch using the Systematic Shoot Sampling method.

(iii) *Measurement of all the shoots on the tree.*—On trees up to about three years old it is probably desirable to measure all shoots. With trees of this size recording is simple. By the time the trees are producing forty or more new shoots one of the other sampling methods could be used.

Summary

Two methods of sampling extension growth on apple trees are described. One method, designated Systematic Shoot Sampling, is suitable for use when a high degree of accuracy is required. An average of twenty to twenty-five shoots, selected in the prescribed manner, should be measured on each tree, more if the trees vary much in size. The other method, Random Branch Sampling, should be used when the trees are of such a size as to require the use of ladders for their measurement and if some loss in accuracy can be tolerated. On young trees of not more than three years old a complete recording will usually be necessary. Individual measurements should be made to the nearest decimetre.

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PLANT PHYSIOLOGY

SEASONAL FLUCTUATIONS IN STEM GROWTH IN THE APPLE ROOTSTOCK CRAB C

By C. R. HANCOCK* and H. W. B. BARLOW

In experiments on the effects of defoliation treatments on shoot growth it was found that internode growth of untreated controls was not constant over the region of the shoot being observed, and consequently allowance had to be made for this variation in considering treatment effects (Barlow and Hancock, 1956a, 1956b). As these experiments were of relatively short duration, it was not possible to ascertain the causes of these fluctuations ; shoots were therefore observed over their complete period of growth for a number of years.

In 1952 and 1953 about 15 untreated shoots were measured at 10-day intervals (Lockard, 1956), and it was shown that the internode completed its growth from a length when it was first measurable in the field (about 5 mm.) to its mature length during the interval between measurements. Consequently in the work carried out in 1954, 1955 and 1956, to be described in this paper, the shoots were measured more frequently, usually at about 5-day intervals. The numbers of shoots observed were 23 in 1954, 33 in 1955, and 23 in 1956.

In 1954 and 1955 each internode was measured from the time it reached a measurable length until no further elongation was recorded. In 1956 similar data were acquired at the same time as observations were being made on leaf growth (Barlow and Hancock, 1958), but the growth of the individual internodes was not followed ; instead, the total length and number of internodes which had matured between the occasions of measurement were recorded, together with the length of the growing tip. At the end of the season the final lengths of the individual internodes were obtained.

Results

In 1954 and 1955 the growth of the shoots began about the last week in May, while in 1956 it began about 10 days earlier. When growth commences a number of small leaves are formed, and then during the first two or three weeks there is a gradual increase in internode length accompanied by a gradual increase in the length of the growing tip of the shoot. These short internodes formed during the early stages of growth may be due to the absence of specific substances formed in the leaves which are required for internode extension (Barlow and Hancock, 1956b). At the end of this period the total length of the shoot is about 20 cm. with about 15 internodes ; of this about 15 cm. and 11 internodes are mature.

Following this phase, the shoot establishes a pattern of growth which is maintained until the end of August. During this period the graphs of shoot length or numbers of internodes are more or less linear, after which growth slows down and virtually ceases in early October (Fig. 1). There is also a linear relation between internode number and shoot length (Fig. 1 inset) indicating a constant internode length (about 2·8 cm.). The length of the growing tip is also found to remain fairly constant over this period, with a length of 4·5-5 cm. and about 4 internodes, so that increases in mature and total length follow a similar course, as also do increases in mature and total internode numbers. The average time taken for any internode to grow from a measurable length to maturity is about 9 days.

It will be seen from Fig. 1 that there are some notable differences between the growth curves for the three years. The earlier commencement of growth in 1956 results in these shoots being about 10 cm. longer by the first week in June than those in the other two seasons, and this difference between the 1954 and 1956 shoots was maintained until the end of August, when in 1956 the growth rate declined sooner than in 1954, so that the final lengths of the shoots in both years were similar. In 1955, however, it will be seen that for the first month growth was very similar to that in 1954, but that after this the growth rate was much higher, and by early August these shoots were longer than the comparable ones in 1956 ; this more rapid rate of growth was maintained, and at the end of the season they were 20 cm. longer than the shoots in the other two years.

The mean growth rate in mm. per day and internodes per day for the three years were : 1954, 9·87 and 0·34 ; 1955, 11·78 and 0·42 ; 1956, 9·44 and 0·38. This much higher average growth rate in 1955 may to some extent be accounted for by the much higher temperatures in that year, the mean

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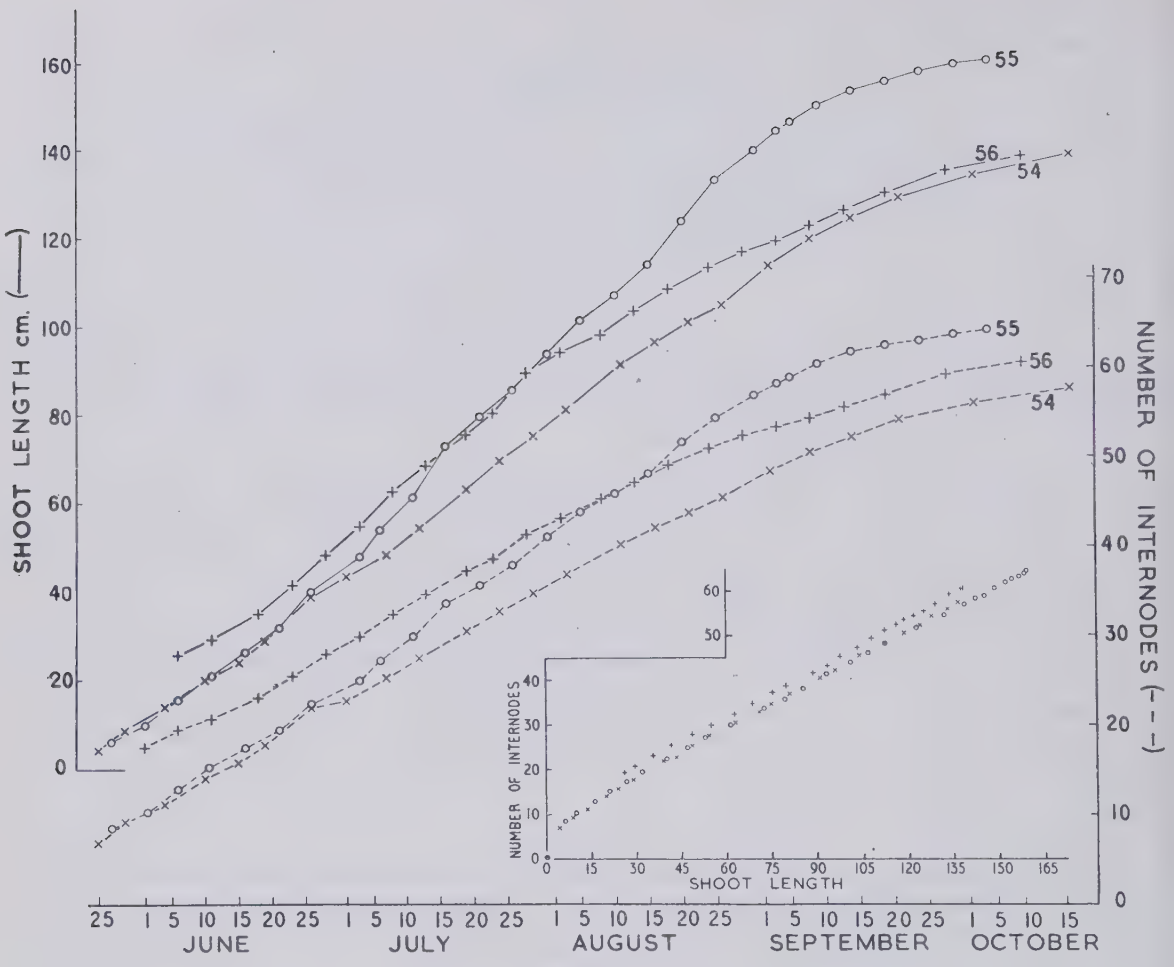

FIG. 1

Growth curves of Crab C shoots during the seasons 1954 (X), 1955 (O) and 1956 (+), showing total stem length (solid lines, left-hand scale), and number of internodes (broken lines, right-hand scale)
Inset : the relationship between number of internodes and shoot length during the three seasons (symbols as above)

daily ' accumulated day degrees ' over the same periods being : 1954, 15·80 ; 1955, 18·18 ; and 1956, 16·06.

Examination of the growth curves shows that superimposed upon the general linear trend of growth there are very marked intra-seasonal variations. This is seen more clearly when the growth rates for the individual periods of growth are plotted as in Fig. 2 (upper two rows).

In general the growth rate of the mature part of the stem (solid lines) follows very closely the growth rate of the whole shoot (broken lines). It will be seen (second row) that at the end of the season there is a difference between the rate of increase in the numbers of mature internodes and the total (i.e. including the tip); this is due to the cessation of growth and consequent reduction in the length of the growing tip to zero, and the inclusion of these internodes which had previously constituted the growing tip in the numbers of mature internodes. As these internodes are short the effect upon the rate of increase in length of mature internodes (top row) is not so apparent.

It was thought that the considerable intra-seasonal fluctuations in the growth rate of the shoot could probably be accounted for by changes in various climatic conditions, and an attempt was therefore made to correlate the growth rates with some of the more obvious factors. In view of the similarity of the rates of mature and total stem growth only the latter has been examined for these correlations. Looking first at the temperature fluctuations expressed as accumulated temperature in day degrees above 42° F. (Meteorological Office, 1928), in each year there is a highly significant correlation between the growth rate expressed in mm./day or internodes/day and the average accumulated

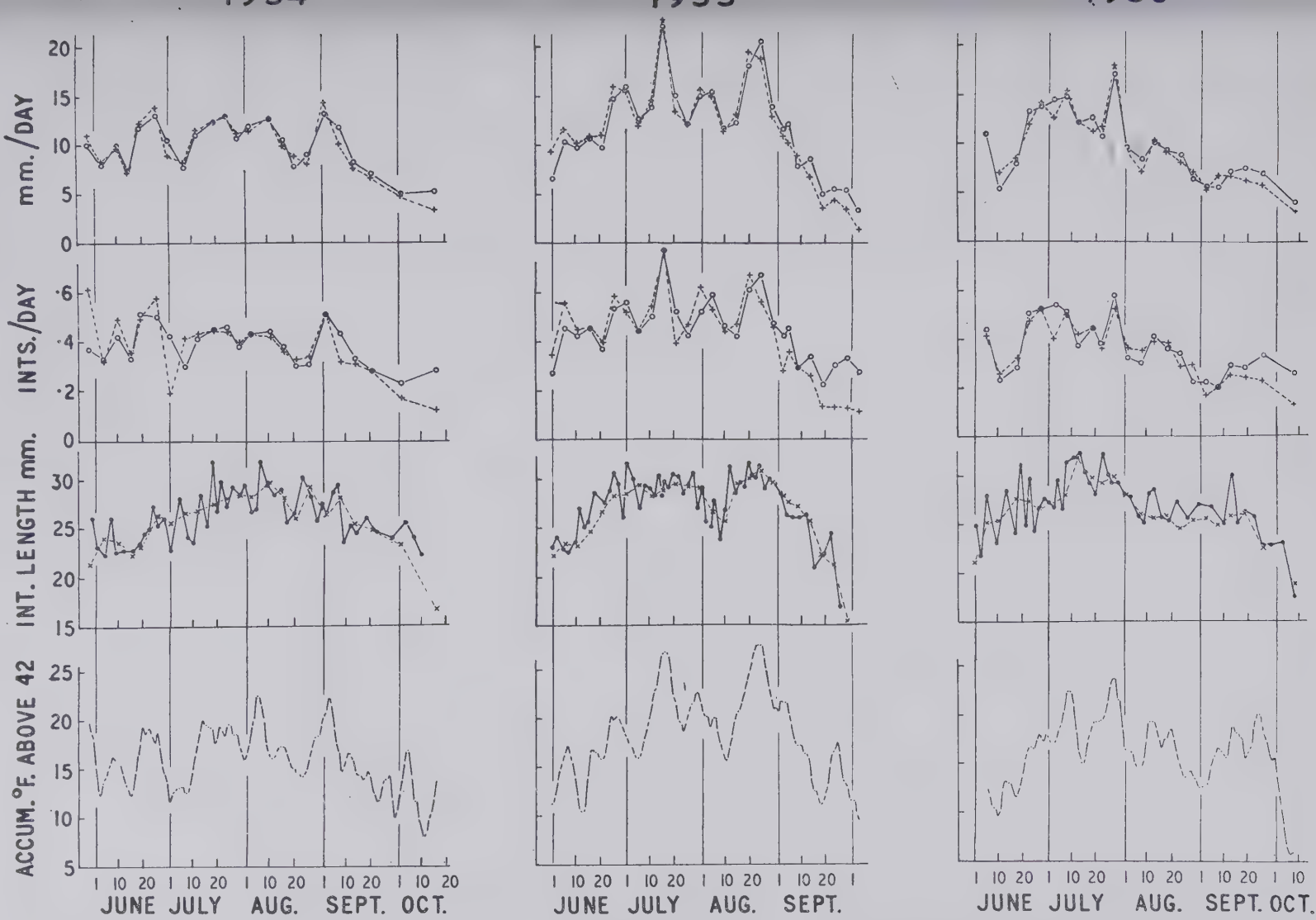

FIG. 2

Fluctuations in shoot growth in 1954, 1955 and 1956 : *Rows 1 and 2*, Growth rates of mature stem (O—O) and total stem (+ – – +) in mm. per day, and number of internodes per day, plotted against the date at the end of each period of observation. *Row 3*, Final internode lengths obtained by the two methods described in the text : average lengths for groups of internodes maturing in each period (X – – X), plotted against date at end of each period, or individual internode lengths from selected shoots growing at similar rates (●—●) plotted against date at which final length was attained. *Row 4*, Accumulated temperature in day degrees above 42° F. ; 5-day overlapping means plotted at the end of the period

Time scales for each year apply to all rows : 1st of each month is shown as a vertical line

day degrees for either the 3, 5 or 7 days prior to the end of the period ; the best correlation was obtained with the 5-day record (Table I). The 5-day overlapping means for temperature over the period under consideration are presented in Fig. 2 (bottom row).

TABLE I

CORRELATIONS AND REGRESSIONS FOR SHOOT GROWTH RATE (MM./DAY AND INTERNODES/DAY), AND FINAL INTERNODE LENGTH WITH TEMPERATURE AND DAYLENGTH

Dependant variate	Year	Correlation coefficients with			Regression equation
		Temperature t	Daylength d	Temperature and daylength	
Shoot growth rate in mm./day	1954	0·863	0·583	0·929	−11·019+0·825t+0·527d
	1955	0·825	0·616	0·952	−23·628+0·813t+1·394d
	1956	0·728	0·748	0·920	−17·481+0·522t+1·252d
Shoot growth rate in internodes/day	1954	0·766	0·633	0·876	−0·423+0·030t+0·029d
	1955	0·680	0·652	0·867	−0·794+0·022t+0·055d
	1956	0·692	0·783	0·933	−0·507+0·015t+0·042d
Final internode length	1954	0·606	0·179	0·629	14·510+0·718t
	1955	0·630	0·324	0·747	18·261+0·485t
	1956	0·502	0·228	0·546	19·190+0·501t

Clearly the decline in growth rate at the end of the season was not accounted for by a decline in temperature, although temperature effects appeared to be superimposed upon this decline. Some factor was therefore sought which showed some such steady decline over this period and the most obvious one seemed to be the hours of daylight (sunrise to sunset), though it is realized that this may not be the best factor to use, and perhaps it only represents an approximation to some closely correlated factor, such as total incident radiant energy ; however, a direct correlation was found between rate of growth and daylength (Table I), and the multiple correlation for growth rate with temperature and daylength was a significant improvement on either separately. The regression planes for these three years differed significantly from each other : in 1954 there is a much lower coefficient for the effect of daylength, while in 1956 the coefficient for the effect of temperature is low. Thus it is seen that although within any one year a close correlation exists between the growth rate and the temperature and daylength, between years there are other factors markedly affecting the relationship ; this may to some extent be due to the methods of expression of the independent variates, and if other terms, such as maximum or minimum temperature, or total incident radiant energy, were used, closer agreement might be obtained ; on the other hand it is almost certain that other climatic factors will be playing a part, particularly in some years, and should be included if it is required to obtain a comprehensive equation which can be used to determine the growth rate in any season.

As already noted, over most of the season there appeared to be a more or less constant internode length, the relationship between shoot length and internode number being more or less linear ; as with the growth-time curves, however, there are superimposed upon this a marked intra-seasonal variation. It is difficult to obtain an average figure for the final lengths of internodes which are comparable as far as their time of development is concerned ; the variations in growth rates of individual shoots result in internodes reckoned either as the number from the tip or the base being very different in relation to their period of development. To overcome this difficulty, two methods were adopted. One was to obtain on each shoot the average internode length of those internodes which matured between the occasions of measurement, and then to obtain an overall average for all of the shoots from these figures ; these results are shown as the broken line in the third row of diagrams in Fig. 2. This method shows up any major changes which occur in internode length during the season, e.g. the reduction in internode length in early August 1955, and a period with long internodes in the middle of July 1956. However, there is a large amount of averaging out of effects, since some internodes may have matured very early in the period considered, while others have only just ceased elongating at the end of that time. The alternative method used has been to select a group of shoots in each year (10 in 1954 and 1955, and 8 in 1956) which grew at a similar rate throughout the year, so that internodes averaged in numerical sequence were comparable in relation to their periods of development. These final internode lengths have been plotted in the third row of diagrams in Fig. 2 as solid points at the average date of maturation of the internode. (For the 1955 data two groups of 10 shoots were

examined which grew at somewhat different rates, and these two groups gave very similar results for the final internode lengths when plotted in this way.)

Correlation coefficients have been obtained for the final internode length with the average accumulated temperature in day degrees above 42° F. for 5 and 10 days prior to the internode completing its growth, and the latter have been found in all years to give the closer correlation. The inclusion of daylength does not improve the correlation significantly (except in 1955 when there is an improvement ($p<0.01$)), daylength playing much less part in the determination of final internode length than it does in the rate of growth of the shoot (i.e. the internode length does not fall off markedly until growth stops at the end of the season). In view of the small improvement achieved by the inclusion of daylength, regression equations have been obtained in terms of temperature alone. Here again there are differences in the effects from year to year, although the large amount of variability does not permit this to be shown up in the regressions : there were no significant differences in either the coefficients or the constant terms between the equations for the separate years. The whole data can thus be represented by the equation :

$$\text{Final internode length} = 17.906 + 0.526t$$

It appears that there is an upper limit of internode length between 30 and 35 mm., so that in 1955 the high temperatures which produced very high growth rates did not produce very long internodes ; this would seem to be due to factors which have not been considered, possibly environmental, possibly concerned with internal organization. The way in which further climatic factors affect the final length of an internode, and the way in which these effects are integrated during its period of growth can probably best be ascertained by measurements of internode growth over short periods ; furthermore it is probably of considerable importance to take into account the growth of leaves on the shoot when considering internode growth (Barlow and Hancock, 1956b). Such work is being started in a detailed study of shoot growth over a short period in 1957.

Summary

The growth of Crab C shoots has been followed in three seasons (1954-6) ; differences were observed between the years, and considerable fluctuations within each season.

Fluctuations in *growth rate*, both in terms of stem length and internode numbers per day, were largely accounted for by variations in temperature and hours of daylight. The *final length* which the internodes attained was not so closely correlated with temperature, and hours of daylight had almost no effect.

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THE EFFECT OF A SUMMER GALE ON LEAVES OF THE APPLE ROOTSTOCK CRAB C

By H. W. B. BARLOW and C. R. HANCOCK*

The severe gale of 29th July 1956 extensively damaged many orchards, trees being blown down or caused to lean at various angles, as reported by Preston (1957) for East Malling Research Station. The high winds also 'scorched' the edges of many leaves, and lacerated others, as did a hail storm eight days later. Apart from these evidences of mechanical damage, there was a general effect on the leaves which showed up as they matured, so that the affected zone of the shoot was readily recognized : the leaves were rather smaller than the average, with a leathery appearance and texture, and were often slightly convex (viewed from above). This zone was particularly clear on stoolbed shoots, which, by virtue of their long growing season, produced normal leaves for a considerable time afterwards.

Among many stoolbed shoots being treated experimentally were 25 untreated Crab C shoots which had been set apart for measurements of leaf growth throughout the season. At intervals of about five days from 27th May to 9th October, the length of all leaves on each shoot was measured from the stage when the leaf was about 10 mm. long until it ceased to grow. The width was measured from the time at which the lamina first flattened out, when it was about 13 mm. wide, the leaf length then being usually some 30 mm.

Results

Of the 25 shoots under observation some were so badly battered by the gale that they had to be discarded ; of the remainder some bore leaves consistently larger or smaller than the average (mean final dimensions for 30-40 leaves on each of 23 shoots were 80·5 mm. long and 58·8 mm. wide), while on others leaves were unfolded from the terminal cluster at a rate very different from the average (the interval between the appearance of successive leaves of 15 mm. length was about 3 days). To obtain a clear picture of the effect of the gale on leaf development, eight shoots were selected which carried leaves of about average size, and which grew at about the same rate from 6th June to 9th October. Final area is well represented by the product of length and width (e.g. Barlow and Hancock, 1956, for this variety) and in the present data final length was closely correlated with this product ($r=0\cdot864$). As the length of the leaf can be measured over a longer period than the width, this dimension was chosen to illustrate the growth of successive leaves on these eight shoots, and average curves for 36 leaves are presented in Fig. 1 ; the leaf numbered 1 on the diagram was about 19 leaves up from the base of the shoot.

Wind velocity increased very quickly ; the records of the nearby Dyne Anemometer for 29th July showed an average wind speed of about 15 m.p.h. from 8 till 10 a.m., with only three gusts of 24 m.p.h., yet between 11 a.m. and 3 p.m. thirty gusts of over 35 m.p.h. raised the average to 25-30 m.p.h. By the evening the wind had dropped to more usual speeds. There was also a marked fall in temperature at the time of the gale.

Because of this abrupt beginning to the gale, and because over most of the season the curves for leaf extension are so steady, it has been thought reasonable to draw the growth curves smoothly up to a line placed just before noon on 29th July, and to join the point of intersection by a different curve to the length observed on 3rd August. While this procedure is admittedly subjective, particularly in those cases where there is only a single observation prior to the gale (leaves 23 and 24), it is considered that this interpretation is most consistent with the whole body of the data.

Up to the time of the gale most of the leaves increased in length at a fairly high rate, and reached a final length of 80-87 mm. Those leaves which emerged from the terminal cluster after the gale (No. 25 onwards) grew at a rather lower rate, and reached final lengths of 73-82 mm. The leaves which were nearly mature at the time of the gale were temporarily checked, but achieved a normal final length (Nos. 16 and 17), while those that were smaller at the time were progressively more adversely affected until the 'gale line' intersected the growth curves near to the inflexion point (Nos. 18-21), after which there was less and less effect (Nos. 22-24), i.e. when the leaf was growing fastest it was most vulnerable to the conditions brought about by the gale.

What was the most important of these conditions—the actual buffeting by the wind (remembering that these data are from leaves which suffered no direct mechanical damage), desiccation of the leaves, or the sharp drop in temperature coincident with the storm ? When the growth rate of each leaf

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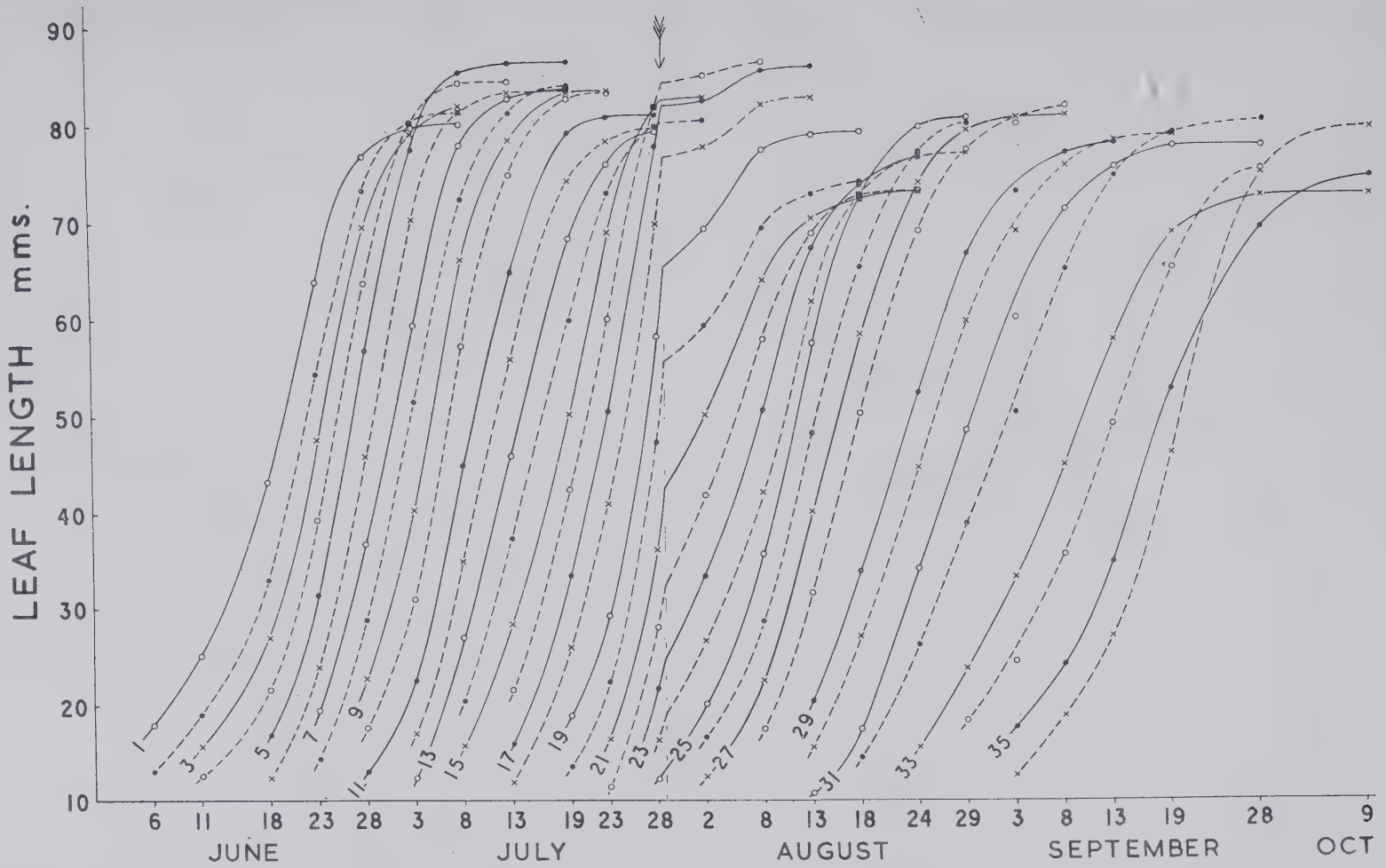

FIG. 1

Growth in length of successive leaves on Crab C shoots in 1956, showing the suggested abrupt change in growth rate at the time of the gale of 29th July, indicated by the arrow. Different symbols and types of line are used to distinguish curves where they overlap

over the approximately linear middle region (between 40 and 60 mm. was used) is plotted against the date at which 60 mm. was reached (Fig. 2) there were considerable fluctuations, and it was found that there was general agreement between these and the variations in temperature, as represented by the 'accumulated day degrees above 42° F.' (Meteorological Office, 1928). The growth rates were therefore correlated with the accumulated day degrees for the periods of 3, 5 and 7 days before reaching 60 mm. length, and while all coefficients were highly significant, the five-day value (r=0·672) has been used throughout.

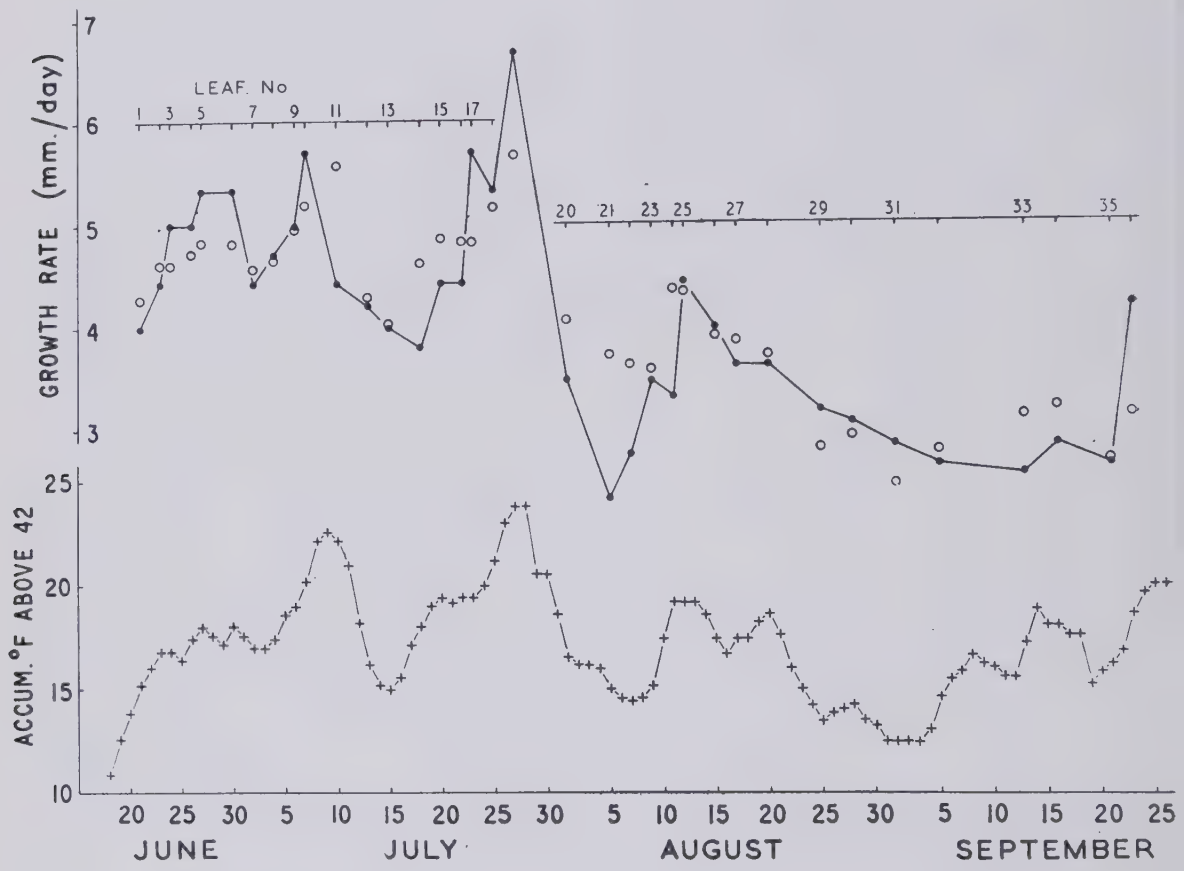

FIG. 2

Upper graph. Observed growth rate of each leaf during its most rapid phase of growth, i.e. between 40 and 60 mm. length, read from Fig. 1, plotted against the date at which 60 mm. was attained (solid symbols). Values calculated from a regression relating growth rate with temperature and daylength are shown as open circles vertically above or below the observed values

Lower graph. Accumulated temperature in day degrees above 42° F.; 5-day overlapping means are plotted against the date at the end of the period

The growth rates also showed an overall decline as the season advanced, and a high correlation was found with hours of daylight (r=0·714); the total correlation between growth rate and both these factors was very close (R=0·865), and was a significant improvement on the correlations with the factors separately. 'Hours of daylight', between sunrise and sunset, although referred to subsequently as 'daylength', is not here intended to have any photoperiodic connotation. The inclusion of hours of bright sunshine (Campbell-Stokes Recorder) did not significantly improve the correlation over that with temperature alone.

In all these calculations the rates of growth of those leaves which might have been affected by the gale between 40 and 60 mm. were omitted, i.e. leaves 20-22. From the rest a regression was obtained from which the rate of growth expected as a result of given temperature and daylength conditions could be calculated:

Growth rate (mm. leaf length per day between 40 and 60 mm.) $= -5{\cdot}579+0{\cdot}207t+0{\cdot}402d$

where t is the mean accumulated day degrees above 42° F. for the five days prior to the leaf reaching

60 mm., and d is the daylength in hours. These calculated rates are shown on Fig. 2 as open circles above or below the observed points.

None of the differences between the observed and calculated rates are significant at the 1 per cent level, and at the 2 per cent level only leaf 21 reaches significance ; the other fairly large differences (Leaves 11, 19, 24 and 36) only attain significance at a probability level of between 5 and 10 per cent.

It is thus evident that as far as the growth rate of the leaf during its most rapid phase was concerned, the effect of the gale was largely accounted for by the associated fall in temperature, only that leaf (No. 21) which was just entering this phase being slowed up more than would have been expected as due to the prevailing temperature and daylength. These data do not suggest what were the other conditions which proved deleterious to leaf growth. The behaviour of the two leaves (far-removed from the gale) which had growth rates lower than expected from the regression, can be adequately accounted for by short-term temperature changes ; leaf No. 11 experienced an abrupt fall in temperature for three days before it was measured on 13th July, but before then it had been growing under high temperature conditions, so that it had probably attained its 60 mm. at a growth rate near to the predicted one — joining the observed lengths by as smooth a curve as possible led to an artificially low ' observed ' rate. The low ' observed ' rate of leaf 24 can be accounted for in a similar way, but the high rates of leaves 19 and 36 have not so far been satisfactorily explained, if, indeed, at this probability level an explanation is required.

The growth rate of the leaf between 20 and 40 mm. is also correlated with temperature expressed in the same way, but as it took rather longer to grow this 20 mm. the temperatures over periods of 5, 7 and 10 days prior to reaching 40 mm. were used in computing the coefficient ; the seven-day period was just the best ($r=0\cdot707$). Including daylength (direct correlation with growth rate, $r=0\cdot646$) improved the correlation ($R=0\cdot908$). It may be assumed that the growth rate of the leaf *after* 60 mm. has been reached, will also be temperature-dependent, but this particular set of data is not very suitable for evaluating the relationship, as it becomes difficult to sample the upper regions of the growth curves in a comparable manner.

The final length of the leaf is obviously determined by its entire history, but it would seem that the growth rate during the middle rapid phase is a very important determinant, being highly correlated with final length ($r=0\cdot836$). The rate over the preceding 20 mm. (20-40 mm.) is also correlated with final length ($r=0\cdot698$), and the regression connecting these functions allows the final length to be predicted from these growth rates. As again the purpose is to find out if the ' gale-damaged ' leaves depart from the predicted values, this time leaves 19-22 were omitted in obtaining the equation:

$$\text{Final length (mm.)} = 67\cdot08 + 1\cdot366G_1 + 2\cdot371G_2$$

where G_1 and G_2 are respectively the growth rates in mm. per day from 20 to 40, and 40 to 60 mm.

The observed final lengths differed significantly from the calculated lengths only for seven leaves ; these differences, and the probability levels at which significance was reached, were :

Leaf No.	16	19	20	21	22	32	33
Observed—calculated length	+4·3	−8·1	−7·0	−5·3	−4·3	+3·9	−2·9
Probability (per cent)	1	0·1	0·1	1	1	1	5

If these differences are considered in descending order of magnitude the part played by the gale becomes clear, though which of the factors in this climatic upset has been involved cannot be determined. Leaf 19 had the highest growth rate between 40 and 60 mm. (Fig. 2), and reached 60 mm. before the gale struck (Fig. 1) ; the long final length predicted was not, however, realized, as the gale conditions followed almost immediately after 60 mm. had been attained. Leaf 20 also had a high growth rate up to the ' gale line ', but because 60 mm. was reached only after this date, the 40-60 mm. average rate was reduced, so that the predicted final length was not quite so much in excess of the observed as it was in the previous leaf. The same argument applies to leaf 21, though here the 20-40 mm. rate was before, and the 40-60 mm. rate after the gale ; by leaf 22 some part of the early rate had also been affected by the gale, and the predicted and observed rates consequently converge. Leaf 33 is the only other leaf with an observed length less than that predicted by the regression, and it suffered from low temperatures just after the warm conditions under which 60 mm. had been reached. Leaves 16 and 32 were longer than the growth rates predicted, possibly due to the good temperature conditions which prevailed *after* 60 mm. had been reached (Fig. 2 ; 23rd-28th July for leaf 16, and 5th-13th September for leaf 32), although as mentioned earlier, it has not been possible to express this relationship quantitatively.

Discussion

In both the features of leaf growth discussed in this paper, the effect of the gale has been shown to be mainly one of an abrupt fall in temperature ; the final length of the leaf is largely determined

by the growth rates of the leaf from 20 to 40, and 40 to 60 mm. length, and these rates themselves are directly related to the concurrent temperatures.

A part of the observed effect of the gale, however, remains to be explained in terms of factors other than those investigated here ; it is hoped to obtain indications of the nature of these factors, and a more precise definition of the effect of temperature changes during different phases of leaf growth, from a detailed study of the growth of a series of leaves which have been measured daily for about a month in 1957. Such an investigation may allow a more complete explanation to be given of the effects described in this paper.

Summary

The effect of the gale of 29th July 1956 on leaf growth has been shown to be mainly due to the associated fall in temperature, although some other factor, at present undefined, also had a significant effect.

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A COMPARISON OF THE GROWTH PATTERNS OF TWO APPLE ROOTSTOCK VARIETIES DURING THEIR FIRST YEAR

By D. H. MAGGS

The experiment to determine quantitative aspects of rootstock/scion interaction described by Vyvyan and Maggs (1954) included the four rootstock varieties M.II, M.IV, M.IX, and M.XVI; of these, M.XVI starts its growth in the spring much later than the others and continues later in the autumn, carrying some foliage well into December. This difference in duration of growth, which amounts to about 20 days in an average year, is a factor whose importance must be assessed before the data of the experiment can be critically examined. Moreover many commercial scion varieties, such as Ellison's Orange, Epicure, and Cox's Orange Pippin, shed their leaves long before such varieties as Bramley's Seedling, King Edward VII, and Worcester Pearmain; whether the leaves of these latter make any extra contribution to the plant's economy during this period has a relevancy to pruning and spraying practice in both nursery and orchard.

Methods and materials

Procedure

The immediate aim was a small scale experiment to compare M.XVI with a variety differing from it, superficially at least, only in its growing season; of the three candidates, M.II came nearest to meeting this requirement. The experimental treatments were designed to make batches of both varieties break into growth simultaneously over an extended period. By following the development of the different batches it was hoped to detect differences in their response to climatic conditions and duration of growth. An early and late harvest would give a measure of the amount of growth occurring late in the season. This approach was partly thwarted by the failure of the various batches to break uniformly into growth and so the treatments themselves need only be briefly described. After cold-storage, plants were brought on in a heated greenhouse (6th and 28th March until 10th April) and then transferred to an unheated greenhouse. Others were cold-stored (until 10th May) and others remained in an unheated greenhouse (6th March until 30th May). All plants were plunged outside on 30th May.

Selection of materials

Since these experiments were primarily concerned with increase in weight, the planting material was carefully selected for uniformity of weight and shape. When the dormant rooted shoots were brought in from the layer beds on 2nd January 1956, they were graded into length classes increasing in steps of 5 cm. The most numerous grade was then graded with a rod gauge into diameter classes, undamaged shoots of the most numerous diameter grade being retained for experiment. The shoots were bedded-in until 9th January, when they were weighed, measured, and pruned to 50 cm. in the laboratory. The dimensions of the two varieties were very similar; before pruning, the average lengths of M.II and M.XVI were 83·1 and 84·6 cm. respectively, and their weights 22·1 and 23·5 g. After pruning to 50 cm. their weights were $17{\cdot}7 \pm 0{\cdot}32$ and $19{\cdot}1 \pm 0{\cdot}42$ g. ($n=20$) with per cent dry weight $56{\cdot}3 \pm 0{\cdot}85$ and $55{\cdot}6 \pm 0{\cdot}81$. Next day the plants were potted into 8 in. pots of John Innes compost and stood outside until required for treatment.

Management

Three shoots were allowed to grow out on each plant, buds being notched if necessary to force them into growth. This was done so that growth would not be restricted by a paucity of growing points, nor yet unnecessarily varied by a variable number of growing shoots. In many cases the third shoot remained a spur, so that full scope was presumably allowed for the expression of treatment differences. Recommended horticultural practices were followed as far as possible, and the plants were always healthy. From the time a shoot had grown about 30 cm., fortnightly applications of 15 g. dried blood were made to prevent nutrient deficiency imposing a common pattern of growth on both varieties.

Results

Contrary to expectation, the trees broke into growth sporadically over a long period and much of the data was analysed as a regression on time, irrespective of storage treatment. It was, however,

possible to group some of the trees into four separate well-replicated groups with buds breaking 7th-14th March, 1st-14th April, 12th-19th May, 19th May-9th June. The means for these groups are discussed in the following section.

Extension growth and leaf area

Frequent measurements were made of stem length (Fig. 1) and number of leaves (Fig. 2). Leaf areas were measured once during growth and at final harvest (Fig. 3). Both varieties followed the same

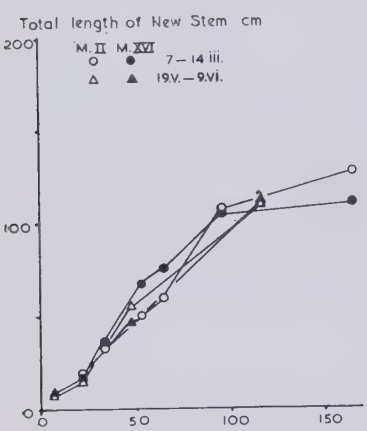


FIG. 1

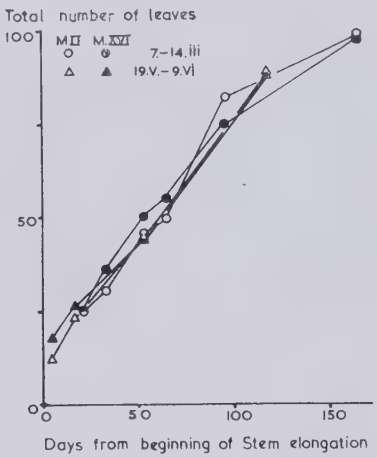


FIG. 2

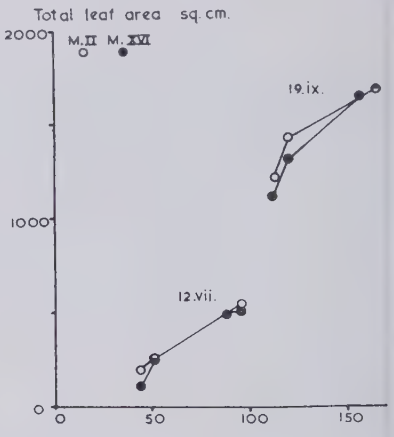


FIG. 3

FIG. 1.—Rate of increase in total stem length
FIG. 2.—Rate of leaf production
FIG. 3—Area increase of foliage on increasingly old shoots measured on 12th July and on 19th September
In these three figures Time 0 is when the bud leaves have expanded to form a rosette and stem-elongation is about to begin. In Figs. 1 and 2, data for groups of intermediate bud-break have been omitted. The dates on the keys to symbols are the dates of bud-break.

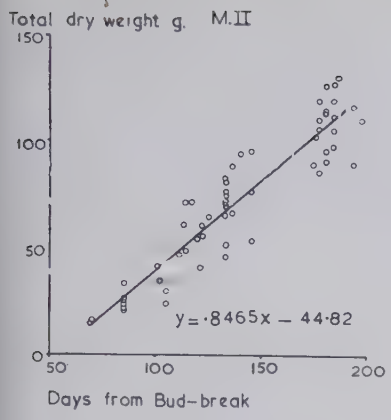
pattern of growth, irrespective of when bud-break occurred, in all attributes measured. Therefore when growth is expressed in terms of leaf area, comparisons between the two varieties are valid, irrespective of theoretical errors in the absolute values (Williams, 1946). It must be remembered that the earlier growth—up to 30th May—was sheltered from the outside winds and drought, and that under field conditions development would go on more slowly; these results are not at variance with the observation that, in the field, M.II reaches full leaf growth more slowly than M.XVI. What is to be inferred is that if M.II broke as late as M.XVI, or M.XVI as early as M.II, both varieties would carry an equal area of leaf on equally long shoots.

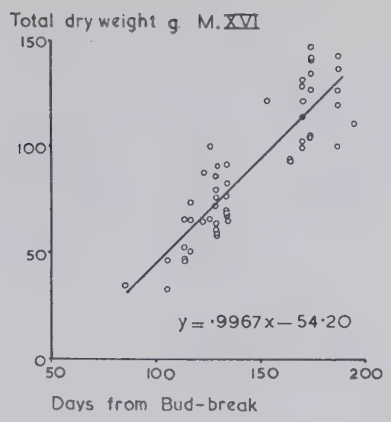
Final weight

It was originally intended to harvest the trees on two dates, but, because of the similarity in growth and the spread of dates of bud-break, all trees were combined into a single harvest. The leaves and young stems were weighed and measured on 19-20th September 1956. Old stems and roots were weighed on 30th October; there may have been some loss through respiration and decay of finer roots but this could have been but a small fraction of the total weight. Sixty-three plants of M.II and fifty-four of M.XVI were available for the calculation of the regression of final dry weight on duration of growth. The equations (over the period 70-190 days after sprouting) were

Dry wt. M.II = 0·85 (Days from sprouting)—44·8 ($r = 0{\cdot}89^{***}$)
Dry wt. M.XVI = 1·00 (Days from sprouting)—54·2 ($r = 0{\cdot}94^{***}$)

These equations accounted for 80 per cent of the total variation, and as Figs. 4 and 5 show, a curved line could not be much more accurate. The growth rates of M.II and M.XVI did not differ statistically. If the equations are plotted so that the date of sprouting is that appropriate to the variety (Fig. 6), M.XVI does not become as heavy as M.II until it has had about 25 days extra growth at the end of the season. The average growing season for M.II is about 1st April to 15th October (200 days) and for M.XVI 15th May to 15th November (180 days), so that in any given year, which variety finishes heavier will be determined partly by the conditions in spring affecting the interval between sprouting dates, and partly by the conditions in the last months of the year determining how long M.XVI goes on growing after M.II has stopped: if these are equivalent, the two varieties will make equal growth.





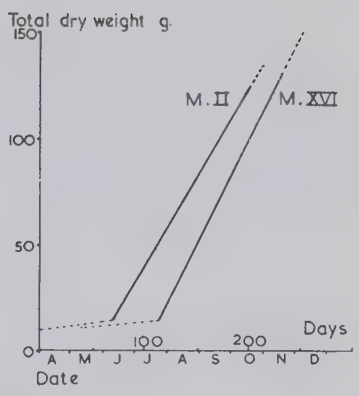


FIG. 4 FIG. 5 FIG. 6

FIG. 4.—Rate of weight increase of M.II, Day o is date of bud-break
FIG. 5.—Rate of weight increase of M.XVI, Day o is date of bud-break
FIG. 6.—Rate of weight increases of M.II and M.XVI according to normal date of bud-break. The time scale is more contracted than in Figs. 4 and 5

Although there was no significant difference between the weight increase of the varieties, it was possible, though unlikely in view of the slight difference in planting weight, that the varieties differed in relative growth rate. An analysis of the log-transformed data allowing for planting weight revealed no significant varietal difference.

Relation between parts of the plant and the whole

In addition to total dry weight, data were obtained of the various parts into which the plant may conveniently, if arbitrarily, be divided—that is leaves, current year's stem, old stem, and roots; the roots were almost entirely of current year's growth. Since leaves and stem length of both varieties followed the same pattern of development, any differences between varieties might be expressed in

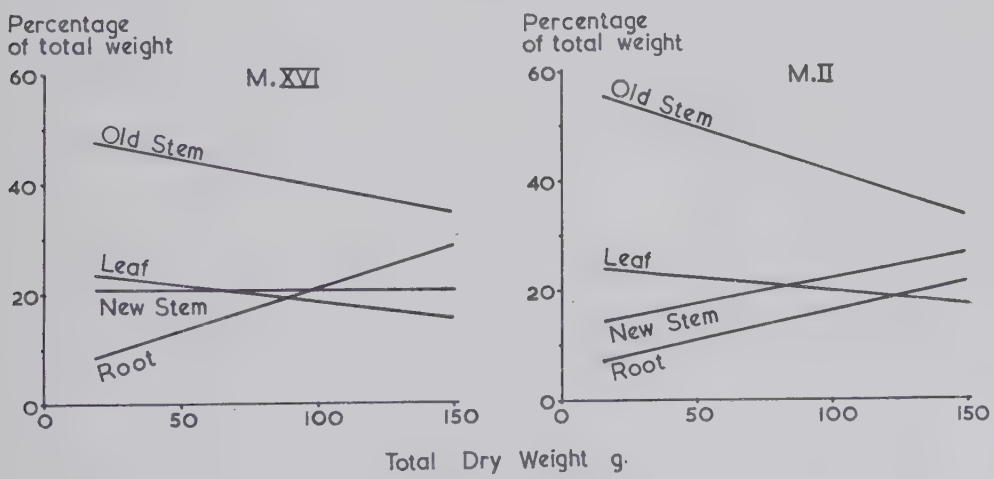


FIG. 7.—The relations between percentage of leaf, stem and root and total dry weight.

the pattern of increment of stem thickening and root growth. Probably because of the uniformity of the planting material, the proportion of the parts to total weight was found to vary with the total weight, and the calculated regressions were significant in all cases except M.XVI New Stem. For Old Stem and for Roots, the slopes of the lines differed significantly between varieties (Fig. 7). Thus for all parts except leaves, the two varieties show quantitative differences in the distribution of increment.

Discussion

The results of this experiment indicate that differences in total weight between M.II and M.XVI may be ascribed to inherent differences connected with the onset and breaking of dormancy, but not with rate of growth *per se*. How much weight would be put on in the autumn under field conditions is not determined, but there is some evidence that M.XVI can grow better under somewhat adverse conditions. Thus, in a subsidary experiment, some plants were grown on in a greenhouse with supplementary lighting until 7th November, when M.II increased from an estimated 65·2 g. dry wt. at the time of transfer to only 67·3 while M.XVI increased from 74·4 to 87·9 g. Other observations have shown that starch formation in persisting apple leaves can occur on sunny days up to mid-December in the field. On the other hand, the paths by which the two varieties reached the same final weight differed considerably, for M.II consisted (relative to M.XVI) of less root as it enlarged and of more old and current stem. Since the ' rootstock effect ' in an ordinary composite fruit tree is brought about by the roots and stem of the rootstock, differences in developmental pattern of the kind described here may be an important factor contributing to this effect.

In view of the importance of the leaves as sites of fixation of radiant energy and carbon dioxide, or as convenient indicators of the size of the metabolic apparatus of the plant, the estimation of the plant's increase in terms of quantity of leaf is a useful measure of the activity of the plant. For young trees, a convenient formula for calculating the ratio averaged over the growing period is

$$A = \frac{\text{Increase in dry weight}}{\text{Leaf dry weight}} \times \frac{\text{Log}_{10}\text{ Leaf dry weight}}{\text{Days from beginning of leaf expansion}}$$

A is thus clearly analogous to Unit Leaf Rate (Briggs, Kidd and West, 1920). In general, the relation between increment and U.L.R. for plants of the same age is not linear; for the data of this experiment, Log. increment and A were linearly related. The regression of each variety was

$$\text{A II} = 0{\cdot}052 \text{ log. increment} + 1{\cdot}80$$
$$\text{A XVI} = 0{\cdot}191 \text{ log. ncrement} + 2{\cdot}90$$

and the regression coefficient for M. II was significantly less than for M.XVI ($P<0{\cdot}001$). The increase in U.L.R. as the plants grew bigger, i.e. as they aged, was possibly a developmental trend similar to that recorded by Watson (1947) for wheat and barley. However, since the proportion of leaf to total weight decreased as the plants aged, the sites for deposition of synthesized materials must have relatively increased, and it is possible that it was this, rather than a specific developmental trend in the plant's metabolism, that was the cause of a rise in the U.L.R. Nevertheless, the difference in slope of the regression lines indicated a real difference between the two varieties. This difference is somewhat surprising in view of the similarity of leaf development; presumably a given area of leaf of M.II was associated with slightly less weight of non-leaf than was M.XVI; this slight difference was combined with a further slight difference in total weight to give a significantly different rate of increase per unit of leaf. An analogous calculation for roots would be of great interest in view of the increasing metabolic functions being attributed to the roots, but so far it has not been possible, because no convenient or logical measure analogous to leaf area or weight has been determined for roots.

These two differences—in distribution of increment, and in Unit Leaf Rate—are perhaps interlocking aspects of the performance of the varieties as rootstocks. Increment distributed as a relatively large root system (M.XVI) results in a relatively greater cambial surface than when deposited as thickening on the stem (M.II). Such an extended cambial surface would presumably afford a more capacious ' sink ' for anabolites than the limited surface of the stem. It follows that the foliage above such a root system can function more rapidly because of the rapid removal of its anabolic products. The circumstances in which this is valid would be those governing rates of synthesis and transport. On the other hand, there is evidence that the respiration of a tree is proportional to its woody surface (Moller, *et al.*, 1954), while varietal differences between respiration per ' unit of living tissue ', have been shown for apple roots, M.XVI having a higher rate than M.IX (Hassan, 1953). Furthermore, the relatively larger root system of M.XVI would presumably have access to a greater volume of soil, thus better buffering the plant against temporary adverse conditions and so better enabling it to maintain the uniform rate of growth necessary for optimum vigour. The net balance of these factors possibly lies in favour of greater growth of a given scion on M.XVI as against M.II. Thus the analysis of growth of these two varieties over even a short period has shown that differences in relative distribution of increment can include in its train consequences which *may* account for much of the so-called rootstock effect.

Summary

Rooted layers of the apple rootstock varieties M.II and M.XVI (of average and late natural bud break) were made to break into growth over a period from early March to mid-June. Extension

growth and leaf number were measured during the growing season and dry weights determined at the end of September.

The time trends of stem elongation, leaf number, leaf area and of dry weight 70-190 days after bud-break were linear and the same for both varieties, and the dry weights of plants having the same growing periods did not differ significantly. The varieties differed in the proportion of stem and root, M.II developing more stem and M.XVI more root for plants of the same weight. The average increase in weight per g. leaf was lower for M.II than for M.XVI. It is suggested that this is due to the larger ' sink ' afforded by the greater cambial surface of the root system of M.XVI, and a mode of action of rootstock effect is adumbrated in these terms.

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FRUIT NUTRITION

THE CONTROL OF MAGNESIUM DEFICIENCY IN APPLE ROOTSTOCK STOOLBEDS: PROGRESS REPORT

By ELSIE M. FORD

Although magnesium has long been recognized as being essential for plant growth, there is little experimental evidence for increased growth or cropping of supposedly magnesium-deficient fruit plants following application of materials containing magnesium. Woodbridge(11) has reported that severely magnesium deficient apple trees, with retarded growth and small, immature fruits, showed no improvement when soil applications of Epsom salt were made, but foliar sprays prevented the development of leaf symptoms and increased fruit size. The recovery of fruit trees (as determined by foliar symptoms and chemical analyses) may be slow when soil applications of Epsom salt are made (7, 10), and Boynton(2, 3) refers to variable results from soil applications of magnesium fertilizers.

At East Malling stoolbed shoots of Crab C, suffering from suspected magnesium deficiency, were sprayed by Barlow and Delap(1) at frequent intervals from June to late August 1952 with 2 per cent $MgSO_4$, $7H_2O$ plus ' wetter '. This considerably reduced the number of leaves developing symptoms, but had no effect on the final length or thickness of the shoots or on the number of leaves produced.

Foliar symptoms similar to those on the Crab C also occurred on the main stoolbed, where further experiments were started in 1953 and 1954, to investigate the effects over a period of years of repeated applications of magnesium sulphate, involving both foliar sprays and soil applications. This paper describes the progress of these experiments up to the lifting of the 1956 crop of rootstock shoots.

Material and methods

The apple rootstock stoolbeds used for this investigation were planted in 1949 on a uniform, freely drained, fine sandy loam overlying organic clay loam on ragstone(5). Severe foliar symptoms of the type attributed to magnesium deficiency were observed in 1952 and growth was unsatisfactory. Before planting, the ground had been heavily dunged. Applications of either straw or farmyard manure have since been made every alternate year, and 3 cwt. of sulphate of ammonia and 1 cwt. per acre of muriate of potash have been applied annually.

Experiment I

In 1952 twenty-four plots, each 10 ft. long and separated from each other by 2-ft. lengths of ' guard row ', were marked out in a stoolbed row of apple rootstock M.IV, selecting those parts of the row most uniform in growth and symptom expression. The number of shoots per plot, their height above soil level and the severity of foliar symptoms were recorded at the end of the season ; these data served to calibrate the plots.

Treatments.—Three treatments, consisting of 0, 3 and 9 foliar sprays of 2 per cent $MgSO_4$, $7H_2O$ with ' wetter ', were applied yearly from 1953, each being represented twice in each of four randomized blocks. In 1953 and 1954, half the plots receiving magnesium sulphate also received sprays of 0·04 per cent Fe-EDTA ; this treatment had no effect and was discontinued.

Spraying with magnesium sulphate, so as to wet all the foliage, began in mid-May and continued at fortnightly intervals, the ninth spray being in early September.

Records.—A record was made towards the end of each season of the proportion of abscissed or necrotic leaves, each plot being divided into five portions, each of which was assessed separately. The percentage number of shoots with necrotic leaves in August was recorded in 1953 and 1954.

At the end of each season, the number of shoots per plot was counted and their heights measured from soil level after the normal ' earthing-up '.

During mid-September 1954 and at the end of August in subsequent years, a composite sample of leaves from near the middle of approximately 10 shoots was taken from each plot. These were cleaned(8), dried at 80° C. and analysed.

Experiment II

Because frequent sprays of magnesium sulphate had prevented the appearance of foliar symptoms on the M.IV rootstocks in 1953, a further experiment was designed to include soil applications of Epsom salt. This experiment was started in 1954 on 20 uniform 10-ft.-long plots of a stoolbed of

apple rootstock MM.102, which had been marked out the previous autumn and recorded as for Experiment I.

Treatments.—The experiment was a 2×2 factorial involving the presence and absence of foliar sprays and soil applications of magnesium sulphate, treatments being replicated five times and randomized within the blocks.

Epsom salt was applied at 4 cwt. per acre to the soil-treated plots in 1954 but in 1955 and in 1956 the rate was increased to 6 cwt. per acre. These applications were made along the row and for 2 ft. on either side in late March or early April, after the soil surface had been broken up.

Eight foliar sprays, similar to those used in Experiment I, were applied in 1954 but the number was increased to 9 in subsequent years.

Records.—Each year the following records were made :

Foliar symptoms were categorized at the end of September or early October by the method described, a similar record being made during August in 1955 and 1956.

The number of shoots produced per plot was counted after lifting ; each shoot was measured and the mean shoot length per plot calculated. In 1955 and 1956 the total weight of rootstocks per plot was recorded at lifting.

Diameters of a sample of shoots in each plot were measured in July and November and the increments in the logarithms of the diameters were calculated to give the relative growth in thickness over that period. In 1954 six rootstocks per plot (fifteen in later years) were selected for measuring. The rootstocks were selected for uniformity each year in July, their height being approximately 15 in. from soil level. Two rings, about 0·5 cm. apart, were painted round each at approximately 10 in. above the soil. Two diameter measurements were made at right angles to each other, between these parallel rings, using calipers ; these measurements were repeated in November in the same places.

Samples of leaves, similar to those described in Experiment I, were taken for chemical analyses.

Soil samples were taken in November 1956 from positions half-way up the mound of the earthed-up row, about 6 in. above normal soil level. Four cores were bulked to give a sample representing each of the depths 0-6, 6-12, 12-18 and 18-24 in. from each of the untreated plots and those receiving Epsom salt. Determinations were made of pH and of the magnesium, potassium and phosphorus extracted by Morgan's(9) reagent, using 1 part of air-dry soil to 2 parts of reagent and shaking for 2 minutes. The amount extracted is hereafter referred to as ' available ' magnesium, etc., and is expressed as parts per million in the extract.

Results

Experiment I

Foliar symptoms.—The symptoms observed and recorded on the M.IV rootstocks consisted of a necrosis, appearing first in early July on leaves at the base and then gradually spreading up the shoots, followed by premature abscission of the affected leaves. The orange-brown necrosis, which usually was not preceded by chlorosis, occurred along the side margins of the leaves and spread inwards between the main veins. As necrosis increased the margins curled upwards. In severe cases up to 80 per cent of the leaves on a shoot became affected.

TABLE I

FOLIAR SYMPTOMS ON M.IV ROOTSTOCK

	Date	Unsprayed	3 sprays $MgSO_4$	9 sprays $MgSO_4$
Percentage of shoots showing symptoms	12.viii.53	34·7	5·6	1·3
	20.viii.54	36·4	5·3	1·8
Mean symptom category ..	6.x.53	4·7*	2·3*	1·0*
	11.x.54	4·7	2·5	1·0
	9.x.55	5·3	2·7	1·0
	28.ix.56	4·7	1·6	1·0

Category 1 represents 0-10 per cent leaves affected
Category 10 represents 90-100 per cent leaves affected
* Corrected treatment means

The 9 sprays of magnesium sulphate completely prevented foliar scorch and defoliation in each year of application. Up to August both in 1953 and 1954, 3 sprays proved almost as effective as 9 in preventing the incidence of symptoms (Table I), although in 1954 the difference was just significant ($P<0·05$). A similar effect, seen during 1955 and 1956, was confirmed by records taken in 1957.

The beneficial effect of the 3 sprays had lessened by the end of each season although the proportion of affected leaves on plants that had received 3 sprays was less ($P<0.001$) than on unsprayed plants.

Number of shoots per plot (Table II).—There was no effect of either 3 or 9 sprays on the number of shoots produced per plot in 1953 or in 1954. In 1955 the numbers were increased for plots sprayed either 3 or 9 times ($P<0.05$) and there was a suggestion of a similar effect in 1956.

TABLE II

MEAN NUMBER AND HEIGHT OF SHOOTS PRODUCED PER PLOT BY M.IV ROOTSTOCK

Date	Mean no. of shoots per plot			Mean height of shoot (in.)		
	Nil	3 sprays	9 sprays	Nil	3 sprays	9 sprays
29.x.53	102*	103*	100*	16·9	17·6	16·8
2.xi.54	112	120	118	13·3	13·9	13·4
2.xi.55	143	179	168	13·3	14·1	14·4
19.xi.56	152	177	181	12·1	13·3	12·9

* Corrected treatment means

Mean height of shoot.—Increases in height of shoot ($P<0.05$) occurred during both 1955 and 1956 in rootstocks sprayed either 3 or 9 times (Table II), but not in 1953 and 1954.

Chemical analysis of leaves (Table III).—There was an increase ($P<0.001$) each year in the concentration of magnesium per unit dry weight of leaf, due to the 9 sprays. The 3 sprays had no effect in 1954 and 1955 but increased the percentage magnesium in 1956 ($P<0.001$).

Although the percentage potassium was not affected in 1954, it was reduced by 9 sprays in 1955 ($P<0.001$) and by both 9 and 3 sprays in 1956, the former having the greater effect.

The Mg/K ratio was increased every year by 9 sprays ($P<0.001$) and in 1956 the 3 sprays had a similar, though smaller, effect.

The percentage nitrogen was increased by both treatments in 1954 ($P<0.01$), but not subsequently.

The percentage calcium was not significantly affected (at $P=0.05$) by either treatment.

TABLE III

CHEMICAL ANALYSIS OF M.IV ROOTSTOCK LEAVES, EXPRESSED AS A PERCENTAGE OF DRY WEIGHT

	17.ix.54			29.viii.55			31.viii.56		
	Un-sprayed	3 sprays	9 sprays	Un-sprayed	3 sprays	9 sprays	Un-sprayed	3 sprays	9 sprays
Mg	0·06	0·07	0·18	0·10	0·11	0·25	0·08	0·11	0·23
K	1·63	1·64	1·61	2·10	1·96	1·79	2·09	1·96	1·78
N	2·82	2·99	3·05	3·12	3·14	3·13	2·93	2·95	2·97
Ca	—	—	—	0·80	0·81	0·75	1·23	1·16	1·09
Mg/K ratio	0·036	0·043	0·115	0·046	0·056	0·142	0·038	0·056	0·126

Experiment II

Foliar symptoms.—The orange-brown necrosis of the leaves of the MM.102 rootstocks began in early July near the base of the shoots, mainly at the margins of the leaves, but occasionally between the main veins ; a narrow band of chlorotic tissue often surrounded the necrotic areas. Affected leaves abscissed readily so that, in severe cases, the base of the shoot was bare while only a few leaves remained green at the apex.

Sprays of magnesium sulphate, with or without soil applications, prevented the incidence of these symptoms every year (Table IV). No differences were apparent at any time during 1954 between soil treated plots and untreated controls. Soil applications of Epsom salt had reduced symptoms by August 1955 ($P<0.05$), but this effect lasted only about 2 weeks. In 1956, a partial reduction of symptoms ($P<0.001$) due to soil applications occurred and lasted throughout the season.

TABLE IV

FOLIAR SYMPTOMS ON MM.102 ROOTSTOCK (EXPRESSED IN CATEGORIES)

Date	Untreated	Soil	Sprays	Soil+sprays
11.x.54	4·8*	4·8*	1·2*	1·2*
13.viii.55	4·2	2·7	1·0	1·0
8.x.55	5·7	5·4	1·0	1·0
24.viii.56	2·2	1·4	1·0	1·0
30.ix.56	4·0	2·5	1·0	1·0

Category 1 represents 0-10 per cent leaves affected
Category 10 represents 90-100 per cent leaves affected
* Corrected treatment means

Number of shoots per plot (Table V).—No effect occurred in 1954, but in 1955 spraying increased the number of shoots ($P<0·05$) and there was a suggestion of a similar effect in 1956 when the variation within treatments was greater. Soil applications alone or combined with sprays had no significant effect.

TABLE V

MEAN NUMBER, HEIGHT AND FRESH WEIGHT OF SHOOTS PRODUCED PER PLOT BY MM.102 ROOTSTOCK

Date	Mean no. of shoots				Mean height of shoot (in.)				Mean fresh wt. of shoot (oz.)			
	Untreated	Soil	Sprays	Soil+sprays	Untreated	Soil	Sprays	Soil+sprays	Untreated	Soil	Sprays	Soil+sprays
2.xi.54	105	105	110	99	15·4	15·4	15·7	15·7	—	—	—	—
23.xi.55	143	133	165	144	20·8	21·8	20·1	20·5	0·51	0·57	0·54	0·55
10.xii.56	124	137	161	139	18·3	17·3	18·1	18·2	0·46	0·44	0·47	0·48

Mean height of shoot (Table V).—Neither sprays nor applications of Epsom salt to the soil affected shoot length.

Mean fresh weight of shoot (Table V).—No significant effect on mean fresh weight of shoot was given by any treatment in 1955 or in 1956.

Mean diameter of shoot (Table VI).—No effect was apparent in 1954 but spraying increased the diameter increment in 1955 ($P<0·001$) and in 1956 ($P<0·05$) ; soil applications produced an increase in 1956 ($P<0·05$). The differences in diameter increment in 1955 reflect marked differences in shoot thickness at the end of the season. Statistical analyses were made on the increments of the logarithms of the diameters but the actual mean increments are given in Table VI.

TABLE VI

MEAN INCREMENT IN DIAMETER OF SHOOTS OF MM.102 ROOTSTOCK (MM.)

Dates	Untreated	Soil	Sprays	Soil+sprays
22.vii.54 to 9.xi.54	1·43	1·44	1·45	1·50
7.vii.55 to 7.xi.55	1·72	1·72	1·82	1·89
11.vii.56 to 6.xi.56	1·73	1·81	1·82	1·86

Chemical analysis of leaves (Table VII).—The percentage magnesium was raised in each year by the sprays ($P<0·001$), but there was no further rise due to soil applications. Although soil applications without sprays had no effect in 1954, there was a tendency (not significant at $P=0·05$) for the percentage magnesium to be raised by this treatment both in 1955 and 1956.

The percentage potassium content of the leaves was unaltered by all treatments except in 1956, when sprays caused a reduction in this element ($P<0·001$).

The Mg/K ratio was increased each year by the sprays ($P<0·001$) but not by soil applications.

The percentage nitrogen was increased ($P<0·05$) by soil applications of Epsom salt, but not by

sprays, in 1954 and there were tendencies for it to be raised by the soil treatments in 1955 and 1956 (not significant at $P=0.05$).

The percentage calcium was reduced by the sprays in 1955 ($P<0.01$) and in 1956 ($P<0.05$). The soil applications had no effect.

TABLE VII

CHEMICAL ANALYSIS OF MM.102 ROOTSTOCK LEAVES, EXPRESSED AS A PERCENTAGE OF DRY WEIGHT

	17.ix.54				29.viii.55				31.viii.56			
	Untreated	Soil	Sprays	Soil+sprays	Untreated	Soil	Sprays	Soil+sprays	Untreated	Soil	Sprays	Soil+sprays
Mg	0·07	0·07	0·20	0·21	0·07	0·10	0·23	0·23	0·09	0·10	0·17	0·18
K	1·18	1·14	1·03	1·14	1·60	1·47	1·32	1·52	1·27	1·23	1·11	1·11
N	2·45	2·51	2·43	2·55	2·85	2·87	2·85	2·92	2·76	2·80	2·74	2·80
Ca	—	—	—	—	0·91	0·91	0·79	0·80	1·02	1·10	0·99	0·96
Mg/K ratio	0·059	0·065	0·194	0·182	0·045	0·067	0·175	0·154	0·071	0·086	0·156	0·168

Soil analysis (Table VIII).—The soil applications of Epsom salt increased the ' available ' magnesium in the top 12 in. of the soil ($P<0.001$), but had no effect on pH or on ' available ' potassium or phosphorus.

It may be noted that the soil was very high in ' available ' potassium and phosphorus and showed high pH values. The ' available ' potassium at the lower depths was unusually high for this type of soil, even allowing for the depth being measured half-way up the mound.

TABLE VIII

ANALYSIS OF SOIL FROM MM.102 ROOTSTOCK PLOTS

Depth in inches from surface	Mg*		K*		P*		Mg/K ratio		pH	
	Untreated	Soil	Untreated	Soil	Untreated	Soil	Untreated	Soil	Untreated	Soil
0-6	21	35	62	62	17	17	0·34	0·56	7·9	7·9
6-12	20	41	49	49	17	17	0·40	0·87	7·7	7·7
12-18	18	22	33	38	11	12	0·55	0·63	7·8	7·8
18-24	17	18	28	30	3	5	0·62	0·67	7·8	7·9

* Parts per million of the element in the extract (one part of air-dry soil to two parts of Morgan's reagent, shaking time 2 min.).

Discussion

The foliar symptoms exhibited on both the M.IV and the MM.102 rootstocks were clearly due to a lack of magnesium, either directly or in relation to other elements. Symptoms were completely suppressed by spraying 9 times during a season and there was a corresponding increase in the magnesium content of the leaves. Spraying 3 times in a season only partially controlled symptoms and in late August had not increased the percentage leaf magnesium content, except in 1956 when symptoms were less severe in these plots than in the previous seasons.

It is unlikely that the higher magnesium values for leaves sprayed 9 times were due to spray adhering to the leaf surface ; this view is supported by the fact that in both 1955 and 1956 for the M.IV rootstocks and in 1956 for MM.102 rootstocks the percentage potassium content of these leaves was reduced, presumably owing to antagonism between magnesium and potassium within the plants. There was no effect on potassium in the first year of spraying M.IV nor in the first two years for the MM.102 rootstocks. This suggests that there was a cumulative spray effect from year to year in the parent rootstock, since the leaves abscise and the current year's shoots are cut off. The symptoms could not have been due to excess of potassium alone since they were prevented even in the first year of spraying ; if potassium is involved in symptom expression then it must be through the ratio of Mg/K, which was increased by the 9 sprays.

Even though foliar symptoms were prevented by frequent sprays, no effect on growth was detected in the first year of the trials on either M.IV or MM.102 rootstocks. In subsequent years there was an increase in the number of shoots produced by MM.102 and a similar tendency with M.IV. In 1955 and in 1956 the mean height of the M.IV shoots was increased by spraying, and this increase was as great with 3 sprays as with 9 sprays, suggesting that the slight foliar symptoms which occurred from August onwards on the 3-sprayed rootstocks did not affect the height or numbers of shoots produced. Unfortunately diameter measurements were not made on the M.IV rootstocks ; possibly these symptoms occurring later in the season could have adversely affected the thickening of the shoot, after extension growth had slowed down(6). The mean height of the MM.102 shoots was not increased by spraying but there was a marked increase in diameter increments ; this, however, was not accompanied by a comparable increase in the mean fresh weight per rootstock as harvested, perhaps because of the variable amount of root present and the rather insensitive method of weighing employed. This point is being further investigated.

The foliar symptoms on MM.102 were not reduced in the first year of application (1954) of Epsom salt to the soil and there was no increase of magnesium in the leaves. In 1955 there was a transitory reduction of symptoms lasting for about two weeks and in 1956 a reduction that persisted throughout the season ; there were small increases in leaf magnesium in both 1955 and 1956. Growth of shoots, measured by number, length or fresh weight, was unaffected by soil treatment either with or without sprays, but in 1956, diameter increments were greater in the treated plots.

The relation between soil applications of Epsom salt, plant growth and mineral composition of the leaves is complicated by the earthing-up of the rootstocks, which, by moving topsoil towards the row, must have increased further the ' available ' soil magnesium. The total increase throughout the profile, raising the level of ' available ' magnesium in the top 12 in. from ' low ' to ' medium ' values, was thus greater than would have been expected from the addition of 16 cwt. per acre of Epsom salt during three years if there had been no such movement of the soil. The low Mg/K ratio in the soil, especially below 12 in. where the potassium was unusually high for that depth, may have been a contributory cause of the poor response of the plants to the marked increase in the ' available ' soil magnesium ; also lack of magnesium may have affected the roots(4), making them unable to respond quickly to Epsom salt applied to the soil.

Thus, although foliar sprays of magnesium sulphate were immediately effective in preventing the appearance of symptoms, and improved the growth of the rootstocks within three years, soil applications have so far had almost no effect on growth. Since, however, the severity of the symptoms in the soil-treated plots is lessening each year, future growth may be affected. Should this occur, a review of the magnesium and potassium status of both soil and leaves will be of value. Further, the economic importance of the observed growth effects remains to be determined.

Although the control of foliar symptoms by magnesium applications in these trials was followed by effects on growth, there was a delay before growth improved and it is clear that the mere elimination of such symptoms cannot be regarded as indicating an immediate effect on growth.

Acknowledgements

The help of Miss A. V. Delap and the general assistance of Mr. J. Elliott in carrying out the trials are gratefully acknowledged. Thanks are also due to Dr. T. Harvey Rose and his staff of the N.A.A.S. at Wye for analysing the soil samples ; also to the Farm Staff for their co-operation.

Summary

Foliar symptoms, which had occurred in stoolbeds of apple rootstocks suffering from suspected magnesium deficiency, were completely prevented each year by 9 foliar sprays of 2 per cent $MgSO_4$, $7H_2O$ and partially controlled by 3 sprays. The leaf magnesium (estimated in August-September), expressed as a percentage of dry weight, was raised each year by 9 sprays, but only during the fourth year by 3 sprays. There were decreases in the percentage potassium due to sprays.

It is clear that the control of foliar symptoms is itself no indication of immediate growth improvement, for foliar sprays had no effect on growth in the first year of treatment, but with continuing application in subsequent years, the diameter increments and the number of shoots produced by MM.102 rootstocks, receiving 9 sprays, were increased ; the number and height of shoots were increased in sprayed M.IV rootstocks, the increments being as great with 3 sprays as with 9.

A total of 16 cwt. per acre of Epsom salt applied to the soil during 3 years markedly increased ' available ' magnesium in the top 12 in., but the evidence suggests only a slight increase in the percentage magnesium in the MM.102 leaves, possibly because of the high ' available ' potassium in the soil which caused the soil Mg/K ratio to remain low. Foliar symptoms were only slightly reduced

after the second year of soil application and growth only improved in the third year, when the thickness of shoots was increased.

Foliar sprays appear to be more effective initially in treating magnesium deficiency than do soil applications.

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SOIL MANAGEMENT EFFECTS ON A NUMBER OF CHEMICAL AND PHYSICAL PROPERTIES OF THE SOIL

By J. E. GOODE and G. C. WHITE

An experiment was started in 1951 to compare the effects of clean cultivation, a permanent straw mulch and a permanent sward on soil moisture through the growing season from April to September, soil pH, organic matter content, total nitrogen, soil aggregate stability and changes in the chemical availability level of the major nutrients in the soil in the absence of any added fertilizers or manures.

This study was intended to be one in which the management effects could be determined without the interference of crop or manurial effects. The information thus obtained could assist in the interpretation of the behaviour of fruit crops growing in soil receiving similar management treatments.

Layout and site

Fig. 1 shows the completely randomized layout of four replicates of each treatment on 12 ft. square plots. The site was fairly exposed and flat, and the soil was a deep river drift of the Barming series(2, 3), consisting of a well-drained fine sandy loam, of uniform light to medium texture, to a depth of 3 ft. or more. At an average depth of 4 ft. the drift deposit passed into a shallow sandy clay loam layer which overlaid the geological material, a free-drained hard calcareous sandstone rock. This series possesses good physical properties and provided the management is good the soil is satisfactory for most fruit crops(2).

The site on plot N3 had probably been under arable cultivation, possibly including hops at times, for at least 160 years(7). Immediately prior to the start of the experiment the land was ploughed, disced and harrowed.

Treatments and management

Treatments were applied in April 1951, and the experiment was terminated in October 1956.

Perennial ryegrass (S23) and Kent wild white clover were sown at rates of 16 lb. and 2 lb. per acre respectively to form the swards. Good establishment was obtained of both grass and clover, the latter persisting well throughout the period of the trial. The swards were cut as close as possible, using a small rotary mower, when the herbage was at an average height of 4 in. This meant that the cutting was done on about twelve occasions during a season. Growth was permitted during late summer according to normal practice for orchard swards and a final cut was given in October. Clippings were left to decompose where they lay.

The mulched plots received an initial application of wheat straw at a rate equivalent to 8 tons of dry matter per acre and subsequently each October at a rate equivalent to 4 tons of dry matter per acre. Thus, when the last application was made in October 1955, a total amount of wheat straw equivalent to 28 tons of dry matter per acre had been used. The annual additions to the initial mulch were quite adequate to maintain a complete surface cover, although by the end of the year the surface litter was usually very thin. The mulched plots received no cultivation, the few weeds that appeared being removed by hand.

An attempt was made to manage the cultivated plots according to the normal practice of summer cultivation with autumn weeds. Thus, weeds permitted to grow during the autumn and winter were incorporated in the spring by digging ; hand hoeing at a frequency normal for orchard soil cultivations maintained the plots relatively clean through the summer. These hand cultivations were much less drastic mechanically than cultivation by tractor-drawn implements as commonly practised in orchards.

Sampling and records

Chemical analyses

Soil cores were taken at 6 in. intervals to a depth of 18 in. and bulked to provide four representative samples of the soil at the time the trial was laid down in 1951. These samples were air dried and kept until the end of the trial in 1956 when further samples were taken from the individual plots. All the samples were then analysed in the N.A.A.S. Soil Chemist's department at Wye. Organic matter content was determined by a modified method* of Tinsley(11), total nitrogen content by the Kjeldahl method, and ' available ' potassium, magnesium and phosphorus on soil extracted with Morgan's reagent(6) ; the soil pH was also determined.

* Modification of the method is contained in private communications.

Soil moisture

A soil moisture tensiometer of the mercury manometer type was installed at 12 in. depth on each plot when the treatments were started. Fig. 1 shows mercury tensiometers on only two plots of each treatment because most of the required soil moisture records had been obtained by the time the photograph was taken, the tensiometers being removed for use elsewhere. In 1954 it was found necessary to obtain a record of soil moisture changes at 4 ft. depth under the swards and gauge-type tensiometers were installed on two of the grass plots. These were situated under the inverted flower pots seen in Fig. 1. The ceramic pots of the tensiometers were sited at the centre of the plots and the manometers or gauges offset by about 2 ft. to avoid interference with the moisture conditions in the vicinity of the porous pots. Soil moisture tensions were recorded early in the morning 2-3 times weekly, starting in April or May and continuing until September or later if necessary.

Gravimetric determinations of soil moisture were made frequently in 1952 and subsequently at approximately monthly intervals from April to September, inclusive, to 1955. Samples were taken from all plots at 6 in. intervals to a total depth of 3 ft. Moisture content was determined by oven drying the soil at 105° C. The difference from the field-capacity moisture content was expressed as a soil moisture deficit in inches of water.

Soil aggregate stability

At the close of the trial, when the soil was moist, large samples were dug from the plots to a depth of 6 in. to supply material for aggregate stability analyses. The pre-treatment of the samples and the analyses were based on, but were not identical with, the method outlined by Low(5). The fraction of dry soil which passed a 5 mm. sieve but was retained on a 3 mm. sieve was used for the wet sieving treatment. Of this fraction 50 g. were placed on a 2 mm. sieve over a 0·5 mm. sieve and immersed in water for five minutes before sieving. The samples were then submitted to wet sieving treatments which ranged over 0 to 200 vertical strokes, each stroke taking the continuously immersed sieves through a 2 in. movement down and up again. Water stability of the soil aggregates was calculated for each wet sieving treatment of the samples, as the percentage of soil (oven dried at 105° C.) retained by the 0·5 mm. and 2 mm. sieves after a correction for gravel and initial moisture content had been made. The percentage water stable aggregates from the two sieves were added together and expressed as a single percentage of stable aggregates $>0{\cdot}5$ mm. because both aggregate fractions were present in about equal proportions with all treatments.

Results

Field observations

Although the cultivated plots could be worked to produce a good tilth, rain quickly dispersed the surface soil and water was frequently held on the surface of the plots.

The lower layers of the straw mulch on decomposition became closely incorporated in the soil immediately in contact with it but did not become distributed in depth. Worm activity seemed to be confined to the immediate surface. The soil under the mulch was continuously moist and after heavy rain it was excessively wet. During sampling there were several occasions when symptoms of inadequate aeration were detected ; some of the soil extracted from the surface zone appeared bluish-grey in colour and some from below the surface layer showed that the natural warm brown colours characteristic of the soil had been replaced by ' cloudy ' browns or greyish-browns. Such areas were quite localized and were probably zones of compaction where treading had been excessive.

The outstanding feature of the soil under the swards was that it rapidly became more friable, granulating readily in the hand, whereas that under the mulched and the cultivated conditions tended to be ' pasty ' when wet and ' cloddy ' when dry.

An interesting observation was made when the moisture tensiometers were removed from the plots. The installation of the tensiometers was done most carefully and the ceramic pots were positioned with their bases at 13·5 in. depth in order that the centre of the pots should be at 12 in. On removal, measurements were taken to check the depth of the pots on each plot. On the mulched and the cultivated plots the depth was found to be within $\pm 0{\cdot}5$ in. of the installation depth but under grass on every plot the depth had increased by 2·0 in. It then became obvious that the ground level of the grassed plots was above the general level of the neighbouring treatments ! No adequate explanation can be given for this effect because volume weight determinations made in 1955 showed no differences between treatments. Contributory factors are thought to be accretion of soil by foot and wind deposition on the small plots, earthworm activity through the whole profile and organic matter additions.

Soil management effects on chemical factors

Table I gives the results of the chemical analyses of the soil at the start of the trial and after five years under each of the treatments. The figures given are the mean values of four replicate determinations.

Fig. 1
Layout of plots

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TABLE I

CHEMICAL ANALYSIS OF THE SOIL BEFORE AND AFTER 5 YEARS TREATMENT

	0–6 in.				6–12 in.				12–18 in.				Significant difference (P=0·05) for treatments within depths
	Soil 1951	Sward	Mulch	Cult.	Soil 1951	Sward	Mulch	Cult.	Soil 1951	Sward	Mulch	Cult.	
pH	6·9	6·8	6·9	6·9	7·2	7·1	6·9	7·1	7·3	7·2	6·9	7·2	0·29
Phosphorus*	8·4	6·3	9·1	7·1	6·4	7·8	7·5	6·4	3·2	2·3	2·3	1·4	1·65
Potassium* ..	54·3	50·0	76·0	43·5	32·3	32·3	55·0	35·8	21·3	22·0	38·8	27·0	9·85
Magnesium*	22·0	19·5	19·5	17·5	19·0	17·0	17·0	17·5	18·0	17·0	17·0	16·5	3·58
Total Nitrogen† ..	0·12	0·14	0·14	0·11	0·09	0·11	0·08	0·08	0·07	0·07	0·06	0·06	0·024
Organic matter† ..	2·32	2·76	2·22	1·89	1·68	1·89	1·40	1·37	1·44	0·97	0·84	0·86	0·643

* ' Available ' P, K and Mg expressed as p.p.m. of the element *in the extract*. (One part of soil to two parts of Morgan's reagent, shaking time 2 min.)

† Expressed as per cent of dry soil wt.

Soil pH.—A reduction in pH occurred under the mulch at depths below 6 in., an effect which brought about a uniform pH through the soil depth examined. There was no effect of grass or cultivation on this factor.

Available phosphorus.—The available phosphorus content in the surface soil of the mulched plots was significantly greater than in either the sward or cultivated plots. There was a significant reduction in the available phosphorus in the 0-6 in. depth under the sward and in the 12-18 in. depth under cultivation after five years, but whereas there was no suggestion of an improvement in either the 0-6 in. or 6-12 in. depths under cultivation the sward appeared to be increasing the available phosphorus content of the 6-12 in. depth.

Available potassium.—Clean cultivation significantly reduced the available potassium content in the 0-6 in. zone ; this may have been due to leaching, because below 6 in. the mean values were higher, thus giving the same mean value for the 0-18 in. depth as at the start of the treatment. The effect of grass was to stabilize the available potassium content at each depth, there being no change from the initial status. The straw mulch had an outstanding effect on the available potassium in the soil, increasing it considerably at all depths. This is a familiar characteristic of mulches which has been reported by numerous workers previously(1, 9, 12).

Available magnesium.—There was a general tendency for available magnesium to decrease under all treatments at all depths. The greatest reduction occurred in the 0-6 in. depth under clean cultivation, a highly significant effect.

Total nitrogen.—Although there were no very marked effects of the treatments on the total nitrogen content of the soil the figures suggest a depletion trend at all depths under clean cultivation and a reverse trend under the sward management. The build-up in the sward plots may be attributable to the presence of a fair proportion of clover. There was a tendency for straw to increase the total nitrogen content in the surface soil but losses from the lower depths resulted in a mean content for the 0-18 in. depth equal to that in 1951.

Organic matter.—There was a general tendency for a build-up of organic matter under the swards and depletion in the cultivated plots, differences between these two treatments being marked in the top 6 in. and only slightly less clear-cut at 6-12 in. The heavy rate of application of straw over the five year period might have been expected to increase the organic matter in the soil, but the data suggest that it may not even have maintained the original level. The very high mean value of the organic matter content at 12-18 in. depth at the beginning of the trial is due to an abnormally high value (2·27 per cent) for one sample. No importance is therefore attached to differences between the treatments at this depth.

Soil management effects on physical factors

Soil aggregate stability.—The results of the aggregate analysis are shown in Fig. 2, each value being the mean of two determinations. Both the rate and amount of disintegration of the soil from the clean cultivated plots were considerably greater than for the grassed or mulched soil. The cultivated soil broke down practically completely after 10 strokes whereas after 50 strokes, when

breakdown had virtually ceased, about 10 per cent of the grassed soil and 5 per cent of the mulched soil remained in the form of water stable aggregates greater than 0·5 mm. in diameter.

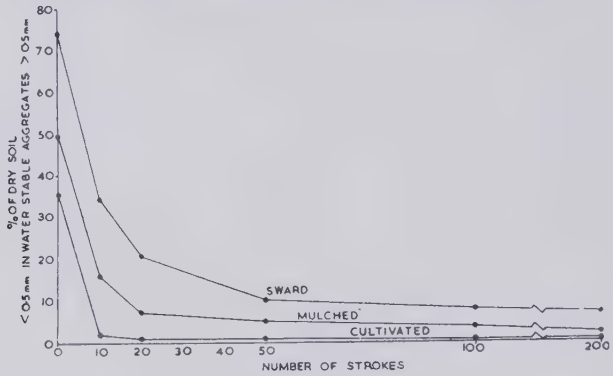

FIG. 2

Soil aggregate stability to wet-sieving after 5 years soil management treatment

Soil moisture tension.—The soil moisture tension changes at 12 in. depth through the growing season of each year 1952-5 are shown in Fig. 3. The effectiveness of a given rainfall or succession of rainfalls for rewetting the soil to 12 in. depth under the different treatments may be assessed by the fall in tension and from the rainfall data. The utilization or conservation of soil moisture to 12 in. depth under the three treatments may be better determined from these graphs by reference to the tension-moisture content relationship given in Fig. 4. This curve was derived from a hundred field samples taken from the 6-18 in. depth on plots of all treatments, at various times when the soil was drying.

Although there was probably a decline in the sensitivity of the tensiometers above about 30 cm. Hg tension, fairly reliable readings to 60 cm. Hg tension were given by the properly maintained tensiometers. The rate of change of tension above 60 cm. Hg with moisture release was so rapid, however, that the tensiometer readings were unreliable and in Fig. 3 a broken line has been used to indicate when the soil moisture tension was greater than 60 cm. Hg.

The influence of cultural conditions on the physical state of the soil moisture, as indicated by the moisture tension, was great and, despite differences from year to year in rainfall distribution, was remarkably similar for a given treatment over successive seasons.

It was only rarely that soil moisture tension under the mulch departed by more than 2 to 3 cm. Hg tension from the field capacity (F.C.) value of about 5 cm. Hg. Drainage losses were excessive, representing 50 per cent and probably more of the rainfall received during the summer. (In the presence of a crop such losses would not generally occur.)

Evaporation losses from the bare soil amounted to the entire rainfall received during summer 1952. The soil moisture tension data for 1952 show that at no time during the summer was the field capacity condition established at 12 in. depth. In the following years wetting to field capacity to 12 in. depth was achieved on 5, 4, and 2 occasions in 1953, 1954, and 1955 respectively, excluding, of course, the rewetting at the end of each season. However, apart from this high loss of summer rainfall from the bare soil, losses from the soil reserves were quite limited as shown by the maximum tensions reached, which did not exceed 25 cm. Hg in the dry summer of 1952 and thereafter only occasionally exceeded 10-15 cm. Hg.

The sward effect on soil moisture tension was in striking contrast to the other two management systems. The moisture tension rose rapidly from about May and then remained high throughout the summer until autumn, except when an occasional summer storm was sufficient to moisten the soil to 12 in. depth.

Soil moisture deficit.—The amplification of the moisture tension data by estimating soil moisture deficits, required the determination of certain soil and soil moisture characteristics.

Field capacity values for the soil were determined from field samples. The permanent wilting percentage (P.W.P.) was determined on three replicate samples from the 0-12 in., 12-24 in., and 24-36 in. depths of soil using *Helianthus annuus* as the indicator plant. The mean values for these limits of the moisture content range, together with volume weight values determined in 1955 on eight replicate samples from each treatment, are given in Table II, which also shows the available water content expressed as inches of water for each 6 in. depth of soil.

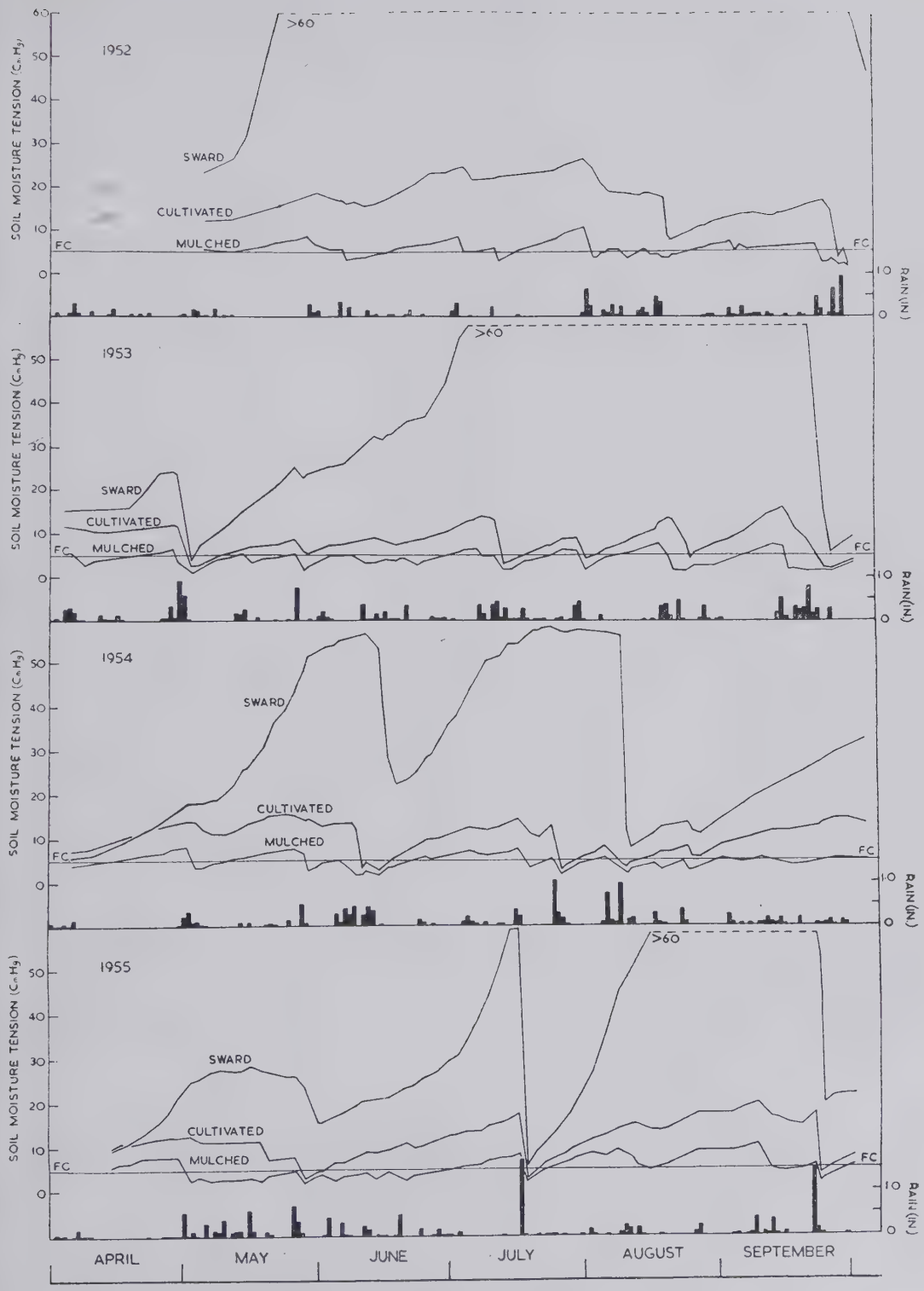

FIG. 3

Soil moisture tension at 12 in. depth under each treatment 1952-5, together with rainfall distribution

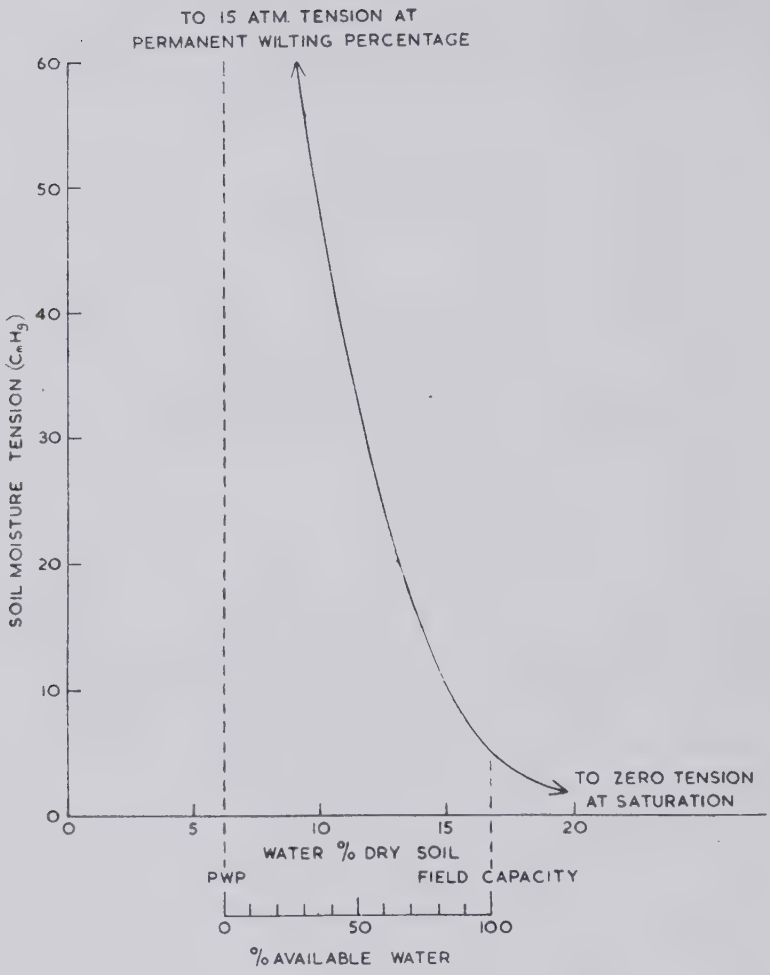

FIG. 4
Tension-moisture content relationship

TABLE II

AVAILABLE SOIL MOISTURE CONTENT

Soil depth (in.)	Moisture content per cent dry soil		Volume weight g. dry soil per c.c.	Moisture content (in.)		Available water (in.)
	Field capacity	P.W.P.		Field capacity	P.W.P.	
0–6	19·3	5·9	1·40	1·62	0·50	1·12
6–12	16·7		1·47	1·47	0·52	0·95
12–18	16·8	6·3	1·55	1·56	0·59	0·97
18–24	16·6		1·40	1·39	0·53	0·86
24–30	16·0	4·8	1·40	1·34	0·40	0·94
30–36	15·3		1·40	1·29	0·40	0·89
Total moisture content (in.)				8·67	2·94	5·73

The coefficient of variation for the moisture content determined from one batch of soil samples in a moist condition, of eight replicates per treatment, was 6·3 per cent. There was no greater variation between similarly treated plots than between replicate observations within plots. The coefficient of variation for volume weight was 8·7 per cent and no effect of treatment was detected

The moisture content per 100 g. of dry soil converted to inches of water had a coefficient of variation of 10·7 per cent. The difference between field capacity and moisture content, in inches, gave the soil moisture deficit which at high values had a coefficient of variation of 12·4 per cent.

Soil moisture deficits estimated for each 6 in. depth of soil have been totalled for 3 ft. of soil and are shown in Fig. 5 for the sampling occasions of 1952-5 inclusive. As seen in Table II, the total available moisture in 3 ft. of soil was 5·73 in. ; this has been indicated on the figure to demonstrate the extent of soil moisture depletion by the different treatments over the four summer seasons.

The soil moisture deficit under clean cultivation generally reached a maximum at about 1·0-1·5 in., although in 1952 a maximum of 2·0 in. was developed and maintained for a considerable time. These losses were not high compared with those in the sward plots, but, because they were sustained chiefly in the surface 12 in. of soil, a very effective barrier to summer rain penetration through this soil depth was formed, as the tensiometer data showed. Once the soil surface had dried, at least 0·5-0·75 in. of continuous rain was required to rewet the cultivated layer and only continuous rain in excess of this amount could be considered useful for root zone replenishment.

Soil moisture under the straw mulch varied between about 0·5 in. surplus (drainage) and about 0·5 in. deficit. Thus the mulch maintained field capacity over the summer seasons and was equivalent in effect to several inches of irrigation water on the cultivated or grassed soil.

The sward's utilization of soil moisture and summer rainfall was very high in all four summers and yet there were appreciable differences between years both in the maximum deficits and in the rate of deficit increase. This did not appear to be entirely accounted for by seasonal rainfall differences; probably as the sward ' aged ' its effectiveness in exploiting soil moisture reserves decreased. This was checked by comparing the deficits determined on soil samples with potential deficits(10) calculated from potential transpiration losses(8) minus rainfall (Fig. 5). Agreement was reasonably good up to a particular deficit value at which the full rate of transpiration loss from the sward was probably checked. This explanation is considered valid because in 1954, when the potential deficit did not greatly exceed 4 in., the actual and potential deficits were in reasonable agreement to the end of the season. In 1952, the rate of moisture loss from the soil was equal to the potential rate up to a deficit of 4 in. A temporary check at this deficit was broken by light intermittent rain and it is noteworthy that the sward then continued to lose moisture from the soil at a rate equal to the potential rate until the entire reserves of the 3 ft. depth of soil sampled had been depleted. In 1953, there were apparent checks to moisture loss from the soil at deficits of 2 in. in May and at 4 in. in July, but though there was recovery from each of these, a further check occurred at 4 in. in August, and the maximum deficit determined was 5 in. compared with a potential deficit of 6 in. In 1954 both the potential deficit and the soil moisture deficit were very similar ; the only suggestion of a check occurred at the maximum deficit (4 in.) developed during the season. Soil moisture loss in 1955 followed very much the same pattern as in 1953 but the full rate of loss was never regained after a severe check at a deficit of about 3 in. ; the maximum deficit determined in 1955 was 4·5 in. when the potential deficit was 6·4 in. Thus, as the sward aged from 1952 to 1955 there appears to have been a marked decrease in its ability to use the soil moisture reserves.

The two 4 ft. deep tensiometers installed in 1954 provided some measure of the moisture loss from the 3-4 ft. depth of soil which was not sampled. Moisture withdrawal occurred from the entire soil depth from June onwards in 1955, but the amount extracted from the 3-4 ft. depth from June to September was estimated at approximately 1 in. and is considered due to water movement and not to root absorption at that depth. The sward made heavy demands on soil moisture, and the maximum potential deficit values for 1952-5 in Fig. 5 provide a good indication of the range and severity of the potential soil moisture depletion by such a sward. Full replenishment of soil moisture reserves under the sward was complete by December or January.

Discussion

The results clearly show defects and benefits of the cultural treatments clean cultivation, straw mulching, and permanent sward. The major defect of clean cultivation was its inability to maintain the soil in a proper physical condition. Though the soil moisture conditions were favourable compared with the sward treatment the cost in respect of other factors made the water gain of dubious benefit by itself. The major disadvantage of the sward system of soil management was the very heavy demand made on the soil moisture which under some conditions could outweigh the benefits of the sward. Mulching, while not displaying so marked a defect as the other two treatments, indicated a potential danger of impaired aeration. Nevertheless, the benefits of the mulch were considerable in respect of increased nutrients and available water. Commercial application of this practice, however, is likely to be limited by availability of suitable mulching material.

The possible influence on fruit crops of these effects of cultural treatments on the soil has been considered elsewhere(4).

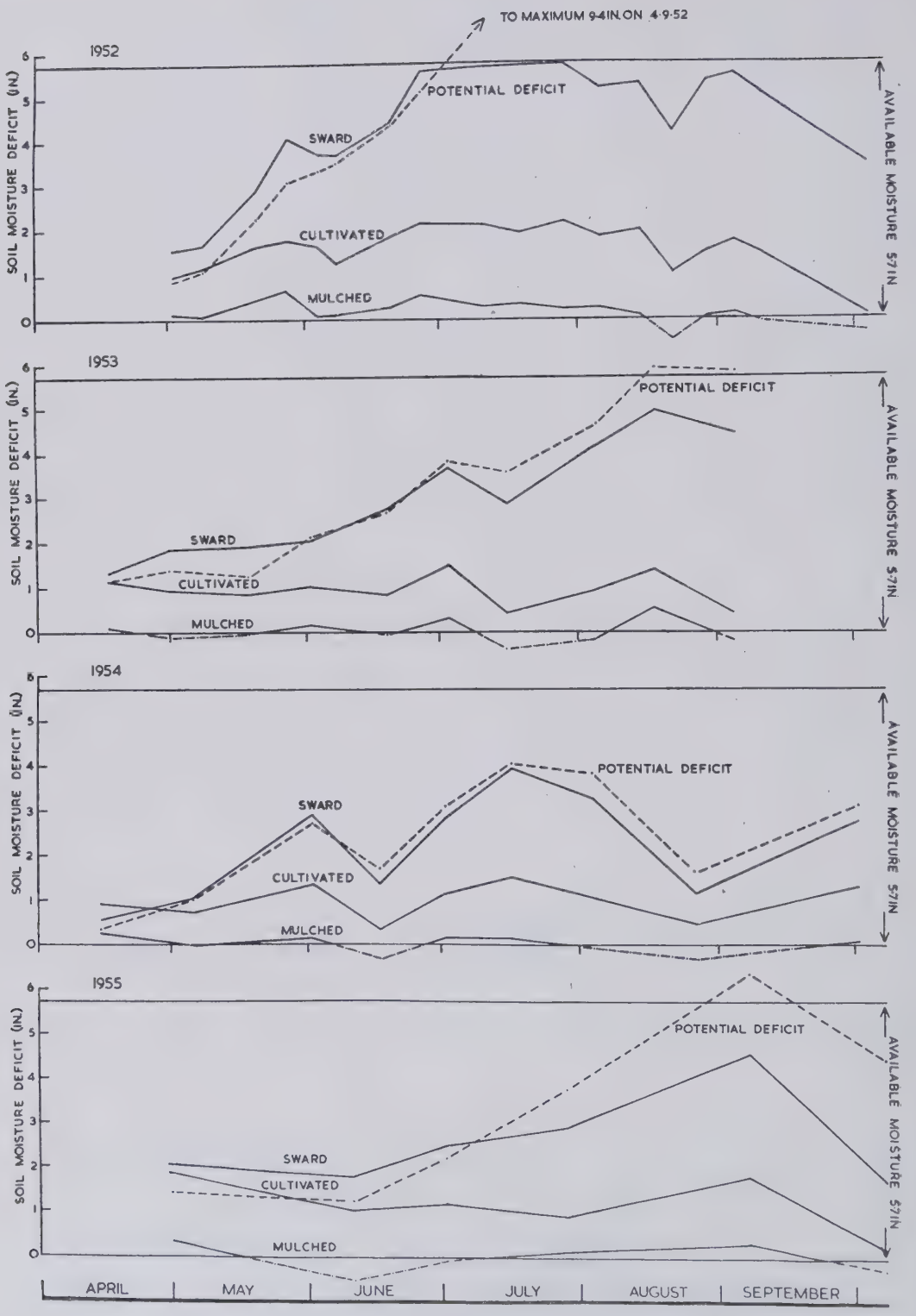

FIG. 5

Soil moisture deficit in 3 ft. soil under each treatment 1952-5

Acknowledgements

We are indebted to Mr. K. J. Hyrycz, who was mainly responsible for the maintenance of the plots and of the instruments and who made the field observation that soil depth had increased under the sward management. We thank Dr. T. Harvey Rose and his staff of the National Agricultural Advisory Service, Wye, Kent, for making the chemical analyses.

Summary

Clear-cut effects on various soil properties have been shown after five years under three contrasting methods of soil management.

Under summer cultivation with autumn weeds the available phosphorus and magnesium in the soil decreased, and there were indications of potassium leaching and of a decrease in total nitrogen and organic matter. Aggregate stability analyses confirmed the field observation that the cultivated soil was in a dispersed state. Evaporation losses from the bare soil amounted to a large part, if not all, of the summer rainfall. Losses from the soil moisture reserves generally reached a maximum of about 1·5 in. and never exceeded 2·0 in. during the period of the study.

The nutritional status of the soil under the sward did not deteriorate except possibly in respect of available magnesium. There was a pronounced increase in organic matter, and the sward also resulted in the most stable structural conditions. The demands made on soil moisture reserves were heavy, despite frequent close mowing, the maximum losses of soil moisture being two to three times those from the cultivated soil. There were strong indications over the 4-year period that as the sward aged its ability to utilize available soil moisture reserves decreased.

Mulching increased the available phosphorus and potassium in the soil but tended to depress the available magnesium slightly. The stable aggregate content of the mulched soil was inferior to that under the sward, but better than that of the cultivated soil. Despite the high addition of organic matter to the soil surface, the organic matter content of the soil was barely maintained at its original level. The moisture conditions under the mulch, in striking contrast to those under the sward and under clean cultivation, remained close to field capacity throughout the summer seasons.

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PLANT PATHOLOGY

A LITTLE CHERRY DISEASE IN ENGLAND

By A. F. POSNETTE and R. CROPLEY

The disease known as Little Cherry has caused considerable losses in British Columbia since it was first observed in 1933. It is one of the most serious diseases of sweet cherry because the fruit becomes unsaleable and because natural spread may be rapid, as has occurred in orchards in British Columbia. A similar disease attacks cherries in the north-west of the United States, but nothing similar has hitherto been reported from Europe.

Symptoms

In 1955, Dr. R. E. Taylor, plant pathologist in the National Agricultural Advisory Service, reported to us the occurrence of small fruit on Waterloo and Black Elton cherry trees in an orchard near the Wyre Forest in Worcestershire; seven trees were affected. Mr. L. F. Clift, Regional Fruit Advisory Officer, could find no environmental conditions that might have dwarfed the fruit on these trees, and therefore he collected budwood for virus tests.

In 1956 and 1957, the trees again developed small irregularly shaped fruit (Fig. 1), which ripened late and had an unpleasant flavour, and it was also noticed that the affected fruit was not eaten by birds. The trees, about 50 years old, had made little growth in recent years, but no leaf symptoms were observed. The disease has not spread since 1955.

Tests for transmission by grafting

The budwood collected in 1955 was used in attempts to inoculate two 4-year-old trees of the Lambert* variety, one of Early Rivers and one of Merton Bigarreau. In September 1956, the test-inoculated Lambert trees developed foliage symptoms in the form of orange-yellow areas bordering veins; similar symptoms accompanied by interveinal purpling occurred in 1957, while the control (uninoculated) trees showed only normal autumn coloration. The inoculated Early Rivers tree produced small fruits in 1957, and in September the leaves developed interveinal purpling that became so intense in October that the tree could be distinguished from healthy trees at a considerable distance. The Merton Bigarreau tree has shown no symptoms.

Discussion

The leaf symptoms developed by the inoculated trees are so like those attributed to the little cherry virus in Canada(3) and the United States(1) that we have concluded that the small fruit condition in the Worcestershire orchard was caused by a similar virus. A second series of transmission tests is in progress to confirm this identification.

The occurrence in England of a disease similar to Little Cherry in Canada at once raises the question whether it has been introduced. So far, enquiries have not revealed any plant introductions from North America to the immediate neighbourhood of the outbreak. Alternative sources of infection are ornamental cherries and wild host plants.

Ornamental cherries, in particular Kanzan (often wrongly called Hisakura) and Shiro-fugen, the varieties most widely planted in gardens and roadside avenues, are generally infected in North America with a virus that causes Little Cherry disease in sweet cherries(2). If an insect vector were present in England, the virus would probably be transmitted to sweet cherry from the ornamentals.

The possibility that the virus occurs in wild *Prunus* and has only recently been transferred to cultivated cherry needs investigation. Wild cherry trees are plentiful in the district where the outbreak has occurred in Worcestershire.

Whatever may be the local conditions which have led to this outbreak it is clearly important that cherry growers should be aware of the danger that other cases of Little Cherry may appear, or may have already occurred and not been reported. If the disease is still limited to one district, it should be eradicated or at least confined by stringent control measures.

* This variety was sent from California as Lambert in 1926 but is different from the Lambert introduced from Missouri in 1955.

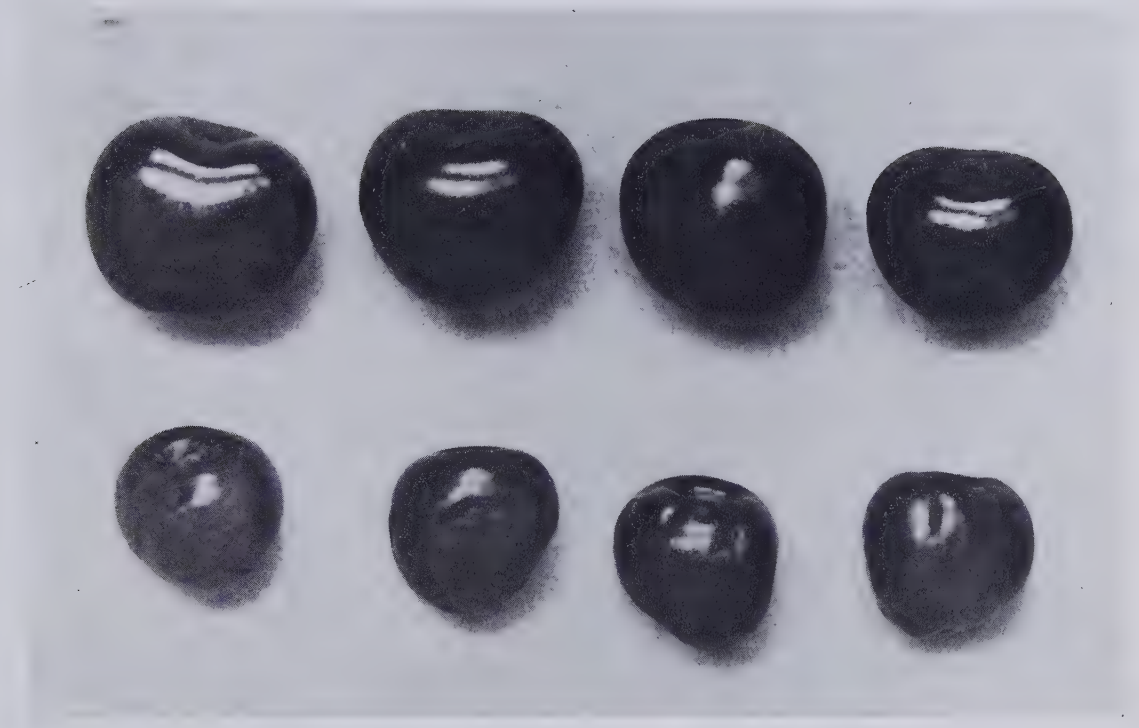

Fig. 1

Waterloo cherries from the Worcestershire orchard ; *above* : fruit from normal trees ; *below* : fruit from trees with Little Cherry disease

[*face page 122*

Summary

Abnormal fruit on trees in a Worcestershire orchard, and leaf symptoms on young trees infected experimentally, indicated a virus disease similar to Little Cherry, previously reported only from North America. The disease is a potential danger to cherry production in England because it spreads in orchards and renders the crop unsaleable.

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ERRATIC TRANSMISSION OF STRAWBERRY VIRUSES BY GRAFTING EXCISED LEAVES

R. CROPLEY

Bringhurst and Voth (1956) described a method of testing strawberry plants for virus infection by grafting excised terminal leaflets onto the petioles of indicator plants. Since this technique appeared to offer advantages over methods in which stolons (Harris, 1932) or stolons and petioles (Harris and King, 1942) are inarched, it was investigated at East Malling in 1957.

Materials and methods

Leaflets cut from the strawberry plants to be tested were grafted into the petioles of vigorous plants of a virus-free *Fragaria vesca* clone (UC-1). Two indicator plants were usually used for each test, and two leaves grafted to each indicator. Several indicators were grafted with leaves from plants with known virus infection to test the reliability of the method. The grafting was done during April in an unheated aphid-proof greenhouse, and plants were shaded from direct sunlight until the grafts united.

Results

Bringhurst and Voth reported that good unions had formed one week after grafting at Davis, California, but at East Malling unions were not reliable in less than two weeks. When examined four weeks after grafting, 152 grafts had united and the scion leaves had remained green and turgid ; 18 had failed.

Data for virus transmission from plants of three varieties known to be infected are shown in Table I. The infected sources were probably carrying strawberry latent virus strain A (Frazier, 1953) in addition to the viruses shown in Table I.

TABLE I

VIRUS TRANSMISSION TO *FRAGARIA VESCA* TEST PLANTS BY LEAF SCIONS

Virus	Test plants	
	Grafted	Infected
Mottle (virus 1)	8	5
Mild Yellow-edge (virus 2) ..	4	2
Crinkle (virus 3)	4	1
Mottle + Crinkle	2	1 (mottle only)

No virus was transmitted from most of the plants whose virus content was being determined. That these plants cannot be judged to be virus-free, however, is clear from the results of making two graft-tests from each of eight plants of a clone of Cambridge Favourite infected with crinkle virus; no virus was transmitted to either *F. vesca* indicator plant grafted with scion leaflets from three Cambridge Favourite plants, and scions from four others infected only one of the two indicator plants. Scion leaves from only one of the plants infected both indicator plants.

Discussion

A possible explanation of the erratic transmission by leaf grafting is that the petioles of the indicator plants became too old for virus passage down to the crown.* The ages of petiole stocks and leaf scions were noted when testing the plants known to be infected, and although it was not possible to correlate successful transmission with age, there was no indication that transmission was more frequent with young petioles than with mature ones.

A plausible explanation would be that the leaflet scions did not contain virus, or that the virus had lost its infectivity before the scions united with the petioles. The low rate of transmission by

* Since this paper was written, the author's attention has been drawn to similar results described by Fulton (1957), who found that positive leaf grafts did not assure transmission of strawberry viruses.

aphids in experiments with yellow-edge and crinkle might suggest that these viruses are not fully systemic, but mottle virus is readily transmitted by aphids from detached strawberry leaves (Posnette and Bovey, 1952) and it would, therefore, seem improbable that the scion leaflets were free from this virus.

The transmission of mottle virus alone from a plant infected with mottle and crinkle viruses (Table I) suggests that leaf grafting may be useful as a means of separating viruses from complex infections. The results would be unpredictable, however, as Storey and Ryland (1957) experienced in isolating a mottle virus by leaf grafts from ground-nut plants with mosaic-rosette disease.

Acknowledgements

The author wishes to thank Mr. L. M. Wassenaar, Instituut voor de Veredeling van Tuinbouwgewassen, Wageningen, who made many of the grafts.

Summary

A leaf grafting technique was found unreliable at East Malling for transmitting strawberry viruses from commercial varieties to *Fragaria vesca*.

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WEED HOSTS OF THE 'PROGRESSIVE' HOP STRAIN OF *VERTICILLIUM ALBO-ATRUM* REINKE AND BERTH.

By G. W. F. SEWELL and J. F. WILSON

Verticillium albo-atrum Reinke and Berth. infects plants through the roots, enters the vascular tissues, and thence may spread to nearly all aerial parts of the plant.

Keyworth (4) demonstrated the importance of diseased bine and leaves in the spread of hop wilt, and suggested that differences in the spread of disease in 'square-plant' and 'Worcester-plant' gardens were directly related to the cultivation pattern, diseased bine and leaf residues being dragged through plantations on the tines, tracks and wheels of cultivation implements. To stress the importance of infected plant residues as a source of inoculum, Keyworth's results are re-presented below in a simplified form (Table I).

TABLE I

WILT INCIDENCE IN PLOTS TREATED WITH INFECTED SOIL AND PLANT DEBRIS

(DATA FROM W. G. KEYWORTH(4))

Inoculum added to plots each 2 yd. sq. and containing 15 Fuggle hops (Replication ×5)	Wilt in 75 hops (%)
1. 2 bush. soil from around diseased plants	7·5
2. ½ bush. soil from around diseased plants	5·3
3. 1 bush. chopped diseased bine	98·7
4. ½ bush. dead leaves from diseased bine ..	84·0
5. Control—no treatment	1·3

Largely as a result of Keyworth's work the practice of clean cultivation throughout the hop season is frequently modified in 'wilt' gardens; cultivations are stopped at about the time when wilt symptoms first appear, that is, roughly, the longest day. Weeds are then allowed to grow unchecked, usually until picking time, when they are cut down and ploughed-in. In early September dense weed stands up to three feet in height may be present, containing a wide variety of species among which fat hen (*Chenopodium album* L.), groundsel (*Senecio vulgaris* L.), and annual nettle (*Urtica urens* L.) are often dominant.

The hop is by no means the sole host of *V. albo-atrum*, which attacks potato, strawberry, tomato, and raspberry as well as a very wide range of other herbaceous and woody plants(2, 6, 8). This host range appears to be limited to dicotyledonous species: a few exceptions to this have been reported but the evidence is not wholly convincing(6).

It was in consideration of this wide host range of *V. albo-atrum* that the vulnerability of some of the weeds which flourish in hop gardens was investigated. The results are reported below and their importance is discussed in relation to the hop wilt problem.

Tests of the susceptibility of weed species under standard conditions

During 1955 weed species, which had previously been noted as common in hop gardens, were collected as seedlings from non-infested soils and planted in John Innes potting compost containing hop bine fragments artificially infected with a 'progressive' strain of *V. albo-atrum*. After twelve weeks the plants were examined for the presence of *Verticillium* by plating surface-sterilized root and stem tissues on nutrient agar. Two plants each of seventeen species (including fat hen, groundsel and annual nettle) were thus tested. *V. albo-atrum* was re-isolated from roots and stems of both groundsel plants but from no other weed species. Although the groundsels showed none of the symptoms normally associated with wilt the pathogen was present throughout almost the entire length of the stems.

Isolations from weed species collected in 'wilt' hop gardens

Collections were made of the commonest weeds in a few badly wilted hop gardens during 1955 and 1956. The numbers of plants sampled rendered impracticable the more exacting isolation

method described above, and the stem bases only were examined by surface sterilization and subsequent incubation in moist chambers(5). All fungi of similar habit to *Verticillium* which sporulated on the stem tissue surfaces were picked off with a sterile needle and subcultured on nutrient agar for final identification.

V. albo-atrum was isolated from all four weed species sampled, viz. fat hen, groundsel, black nightshade (*Solanum nigrum* L.), and annual nettle. In one collection *V. dahliae* was isolated from groundsel, and a very mildly pathogenic species, *V. nigrescens*, was isolated from the first three named weeds. The results of these isolations are presented in Table II. In general these isolation figures are low, but it must be borne in mind that the technique used is not an efficient one. Also, on completion of these samplings slight evidence was found to suggest that *V. albo-atrum* may penetrate to the stem tissues (which alone were sampled) particularly with approach of senescence of the hosts ; thus, with groundsel, *V. albo-atrum* was isolated from 4·7 per cent of plants healthy in appearance and from 13·5 per cent of plants approaching senescence.

TABLE II

ISOLATION OF *VERTICILLIUM* SPECIES FROM WEEDS COLLECTED IN 'WILT' HOP GARDENS

Weed species	Number collected	*Verticillium* spp. isolated (per cent)		
		V.a.a.	V.d.	V.n.
Groundsel	393	10·0	1·0	3·0
Fat hen	378	5·8	—	2·1
Annual nettle	212	1·9	—	—
Black nightshade ..	100	1·0	—	5·0

V.a.a. = *V. albo-atrum.* V.d. = *V. dahliae.* V.n. = *V. nigrescens.*

The pathogenicity to hop of weed isolates of *V. albo-atrum*

Although isolates of *V. albo-atrum* were obtained from weeds growing in hop gardens with 'progressive' wilt the possibility remained that they were either strains of the fungus non-pathogenic to hop, or mildly pathogenic forms of the 'fluctuating' type. Consequently six isolates were tested in the hop pathogenicity testing tanks(7), using Fuggle N as indicator. From the results there can be little doubt that all weed isolates tested were virulent strains of the 'progressive' type (Table III).

TABLE III

PATHOGENICITY TO HOP OF SIX WEED ISOLATES OF *V. ALBO-ATRUM*

Source of isolate	Fuggle N bine killed or severely wilted (per cent)
1. Groundsel	100
2. Groundsel	100
3. Fat hen	100
4. Fat hen	100
5. Annual nettle	100
6. Black nightshade	100
7. Control—standard 'progressive' ..	92
8. Control—standard 'fluctuating' ..	0

Hops inoculated : 18.iv.57. Wilt symptoms recorded : 16.viii.57.

Discussion

By simple analogy with Keyworth's results, presented in Table I, the ploughing-in of diseased weed material should increase the inoculum potential(3) of the soil. This conclusion, however, is not necessarily correct for the analogy is less close than is immediately apparent. The inoculum used by Keyworth was totally infected material of a type not readily decomposable (hop bine and leaf petiole). In contrast, only a very small proportion of the total weed flora tissues may be infected ; generally the tissues are green, succulent and readily decomposable and their incorporation into the soil will produce ameliorating effects on the soil microflora. Indeed, provisional evidence from experiments

in progress suggests that the survival of *V. albo-atrum* over *relatively short periods* is less in soil supporting vigorous *annual* weed cover than in soils devoid of plant growth. The mechanism of this effect is not fully understood but it seems probable that factors may be involved similar to those postulated for the controlling effect of green manuring on a number of other soil-borne pathogens(3). Consequently, at least two major, counter-acting factors must be considered when attempting to estimate the significance of weed hosts in infested hop gardens :

(1) The degree of sensitivity and abundance of susceptible species and varieties of weed hosts permitting *V. albo-atrum* to colonize their *living* tissues and so to multiply.

(2) The beneficial effects which may be exerted directly or indirectly by a vigorous annual weed flora in reducing the period of survival in *dead* plant tissues.

The role of weed hosts in *Verticillium*-infested hop gardens is therefore difficult to assess immediately and definite recommendations must await the results of investigations in progress.

Ecologically, the occurrence of weed hosts of the ' progressive ' wilt pathogen is clearly of great importance. In particular, survival and spread of the fungus in naturally occurring weed populations may be of considerable significance in the epidemiology of the disease. At the same time the danger of spread of the ' progressive ' strain in wild plant communities should not be exaggerated : in all probability it would be very slow for there must rarely occur large areas of uniformly susceptible wild host plants. The situation in such communities can be described no better than in the words of F. C. Bawden(1) : ' Plants, of course, get diseased when growing in areas untouched by agriculture, and diseases have doubtlessly sometimes limited the increase of wild species that might otherwise have become dominant. But in most " wild " habitats the plant populations are varied, mixtures of very many different species, and pathogens do not have too easy a time. If one plant becomes parasitized, its neighbours are likely to be different species and not to be susceptible to the same parasites. Each plant is a selective ecological niche, favouring only a few parasites, and spread from one suitable niche to another is a chancy thing. With neighbouring plants supporting different populations of parasites (and saprophytes), the microflora in any region is proportionately as rich in species as is the macroflora, and no one microbe is especially numerous.'

Summary

Some common hop garden weeds have been shown to be susceptible to infection by the ' progressive ' hop strain of *V. albo-atrum*. Problems arising from this discovery are discussed.

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THE NICKEL CONTENT OF HOP PLANTS WITH REFERENCE TO NETTLEHEAD SYMPTOMS

By J. T. LEGG and P. J. ORMEROD

Nettlehead has been recognized as a virus disease since its graft transmission was confirmed by Keyworth and Davies(3), but no vector or other means of spread has been discovered to account for its recurrence in hop plantations. During an investigation of this problem Hudson(1) observed that the heavy-metal content, particularly of nickel was higher in soil, leaf, and cone samples from nettlehead-infected hop plants than from symptomless plants in the same field. He also noted a positive relationship between nickel concentration and symptom severity in diseased plants, although in no case was the former of the high order usually associated with visible symptoms of metal toxicity. Hudson suggested, therefore, that the amounts of nickel present in nettlehead-infected plants may have rendered them ' prone to attack by the nettlehead virus '. In view of the variability and often transient nature of Nettlehead symptoms on nettlehead-infected plants this hypothesis was of considerable interest, and it was decided to study the problem further in experiments planned jointly by the Brewing Industries Research Foundation, Wye College and East Malling Research Station. This paper describes experiments carried out at East Malling with the object of determining firstly the symptoms of nickel toxicity in healthy hop plants and, secondly, whether a high nickel substrate was essential for the development of typical Nettlehead symptoms in plants infected by nettlehead virus.

Preparation of test plants

The nettlehead-sensitive variety Early Prolific, which develops symptoms in the year of infection, was used in both experiments. Layer-cuts of a healthy clone, rooted in John Innes No. 2 compost, were thoroughly washed, and replanted in washed Bedfordshire sand. By extraction with 0·1 N HCl it was estimated that each pot of sand contained 0·2 mg. of nickel. Although this figure appears high it is probable that only a small proportion of the nickel was available to the plants. The plants were established and pruned to leave a single stem before treatments were started and were kept in an insect-proof glasshouse throughout.

The stock solutions of major and trace elements (Table I) were made up separately in distilled water and these then diluted 10 and 100 times respectively to give the final concentration of nutrients

TABLE I

COMPOSITION OF THE NUTRIENT STOCK SOLUTIONS

Major element solution	g./litre	Trace element solution	g./litre
A.R. KNO_3	5·2	A.R. $MnSO_4.4H_2O$	0·120
Pure $Ca(NO_3)_2$	8·8	A.R. H_3BO_3	0·186
A.R. $NaNO_3$	4·9	A.R. $ZnSO_4.7H_2O$	0·022
A.R. $NaH_2PO_4.2H_2O$	2·0	A.R. $CuSO_4.5H_2O$	0·020
A.R. $MgSO_4.7H_2O$	4·0	A.R. $(NH_4)_6MO_7O_{24}.4H_2O$ ..	0·003
		Pure $FeC_6H_5O_7.3H_2O$	5·175

as shown in Table II. The pH value of the major solution was 5, that of the minor solution 6, and that of the drainage from the pots, approximately 7·5. Each plant received 200 ml. of one nutrient solution daily, using the major element and trace element solutions on alternate days. Every seven days each pot was washed with 4 l. of distilled water to remove accumulated salts.

Experiment I. Symptoms of nickel toxicity in uninfected hop plants

After the plants had grown for 47 days in sand culture, nickel (as A.R. $NiSO_4.7H_2O$) was included in the trace element nutrient solution so that each of the ten plants received a different concentration

TABLE II

FINAL CONCENTRATIONS OF THE ELEMENTS IN THE NUTRIENT SOLUTIONS

Major element solution	p.p.m.	Trace element solution	p.p.m.
Potassium	209 K	Manganese	0·32 Mn
Nitrogen	260 N	Boron	0·33 B
Phosphorus	40 P	Zinc	0·05 Zn
Magnesium	39 Mg	Copper	0·05 Cu
Calcium	149 Ca	Molybdenum	0·02 Mo
		Iron	5·00 Fe

ranging from 0·1 p.p.m. to 80 p.p.m. (Table III). Thereafter frequent records were made of the condition of the plants. On the thirteenth day after the first nickel application the stem of each plant was cut into three equal lengths and the nickel content of the leaves from each length and of the roots from each plant was determined by a D.C. arc spectrographic method (Table III).

TABLE III

EXPERIMENT I. NICKEL CONTENT AND SYMPTOMS OF VIRUS-FREE PLANTS AFTER THIRTEEN DAYS TREATMENT

Nickel dosage rate (p.p.m.)	Leaf and stem symptoms	Nickel content*			
		leaves			roots
		top	middle	bottom	
80, 60, 40, 20	Chlorosis of tissue adjacent to veins, but sometimes more general. Red-brown vein necrosis with some necrosis of adjacent tissue. Leaves curled. Stem necrotic behind tip.	119	65	121	2,500
		156	137	169	2,775
		183	134	196	1,940
		150	186	194	1,800
10	Chlorosis of tissue adjacent to veins. Red-brown vein necrosis.	117	116	199	1,900
5, 2, 1	Chlorosis of tissue adjacent to veins. Leaf edge dark green.	84	79	83	1,315
		36	31	37	590
		25	12	26	400
0·5, 0·1	Yellow mottle.	10	10	12	194
		15	8	15	43

* p.p.m. of dry matter

Results

Six days after the first addition of nickel a yellow mottle was evident on the leaves of all the plants. By the ninth day the leaves of plants treated with 1 p.p.m. or more of nickel had developed a dark green edge, while in addition, the veins and parts of the leaf edge became necrotic on those plants receiving 40 p.p.m. or more of nickel. Some of these initial symptoms were only transient, especially on plants receiving the largest dosages. A summary of the final record taken on the thirteenth day and results of the analysis are shown in Table III.

Discussion

The significance of the yellow mottle on the leaves is uncertain as this symptom frequently occurs on hop plants grown in the glasshouse. The other symptoms were most severe on plants receiving the highest dosage of nickel, and as the severity was also related to the nickel content of leaves and roots, it seems probable that these symptoms were caused by a toxic concentration of this metal. It should be stressed that all the recorded symptoms were clearly distinguishable from those of Nettle-head in the Early Prolific variety. The above results are similar to those previously obtained by Thompson(4) using Fuggle hops.

The nickel content was consistently higher in the roots than in the leaves, and generally lowest in the leaves in the middle region of the stem.

Experiment II. Disease symptoms and heavy-metal contents of nettlehead virus infected plants grown in a low nickel substrate

The ten test plants in this experiment were grown in the same nutrients as before but received no nickel other than that already present in the sand. After 28 days, five plants were bottle-grafted with nettlehead-infected scions and five control plants with healthy scions. After a further 69 days all the leaves above the graft on each plant were detached and the copper, molybdenum, manganese, nickel, iron, and zinc contents determined (Table IV).

TABLE IV

EXPERIMENT II. HEAVY-METAL CONTENTS (P.P.M.) OF LEAVES FROM HEALTHY AND NETTLEHEAD INFECTED HOP PLANTS GROWN IN SAND CULTURE

Symptoms on plants analysed	Cu	Mo	Mn	Ni	Fe
Typical Nettlehead	16·5	2·9	41·0	11	121
	13·0	2·9	33·0	9	119
	12·5	2·0	44·0	<9	125
	13·0	2·9	37·0	<9	141
	16·0	3·0	33·0	<9	152
None	10·5	1·7	38·0	<9	105
	15·0	1·1	32·0	<9	101
	9·0	1·1	22·0	<9	107
	11·0	1·3	28·0	<9	109
	24·5	1·1	29·0	<9	98

Zn negligible in all samples

Results

All five infected plants developed typical Nettlehead symptoms, while the five controls remained symptomless. Nickel was demonstrated in the leaves of all the experimental plants but at concentrations appreciably less than those associated in the previous experiment with symptoms of nickel toxicity. No difference was detected between the nickel content of healthy and infected plants, although this result could conceivably reflect the relative insensitivity of the method used for the nickel estimation. The levels of molybdenum, iron, and manganese on the other hand, were higher in the infected plants than in the controls ($P<0{\cdot}001$, $0{\cdot}01$ and $0{\cdot}1$ respectively). No consistent differences were observed in the copper and zinc contents of infected and uninfected plants.

Discussion and general conclusions

These results support Hudson's(1, 2) observation, that there is a relatively high heavy-metal content in leaves of plants affected by Nettlehead disease, but they do not suggest that a high nickel content is essential for the development of normal Nettlehead symptoms.

The precise nature of the relationship between heavy-metal content and Nettlehead disease is as yet uncertain, but the evidence so far available suggests that the former is most probably a symptom rather than a predisposing factor in Nettlehead disease of the hop.

Acknowledgements

The writers wish to thank Mr. A. C. Mason for advice on the sand culture work and for the spectrographic analysis, and Mr. F. C. Thompson (Wye College) for recommending the nutrient solutions used.

Summary

The addition of 1 p.p.m. or more of nickel to Early Prolific hop plants grown in sand culture induced toxicity symptoms within 13 days. These symptoms were different from those caused by nettlehead virus. Nettlehead-infected Early Prolific plants developed typical disease symptoms

when grown in sand culture with a low nickel content. Some of the heavy-metal contents of the leaf samples from these infected plants were significantly higher than those from healthy plants, and it is suggested that this is symptomatic of the disease.

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ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1957

By A. M. MASSEE

1. Stag Beetle *Lucanus servus* (L.)

A stag beetle larva found just below ground level feeding at the base of an apple tree at Ditton, Kent, was probably the cause of the death of the tree. The tree was first observed to be unhealthy two years ago, but in 1956 it still produced normal foliage on many of the branches although there was considerable rotting below ground where the larva was feeding.

The usual host of the stag beetle larva is elm but it also feeds on the roots of apple and cherry.

2. Beetle feeding upon the Silver Leaf fungus

Numerous larvae of the fungus-feeding beetle *Endomychus coccineus* L. (*Endomychidae*), a species closely allied to lady-bird beetles, were observed throughout the winter feeding on the fructifications of the Silver Leaf fungus infecting a number of dead and dying plum trees at Ditton and East Malling.

The writer is indebted to Mr. D. W. Jenner for bringing this interesting insect to his notice.

3. Coxcomb Prominent *Lophopteryx capucina* (L.)

Larvae of the Coxcomb Prominent were noted in October, 1956, in several orchards near Kirdford, West Sussex, and also on apple at East Malling later in the month. Although mature fruits were still on the trees, the larvae did not feed upon them.

The larva is green with a darker line along the back, a yellow line at the sides, and two reddish-brown wart-like projections on the back of segment eleven; the colour may be variable. There are two generations a year, in May-June and July-August. The usual hosts are oak, hazel, birch, beech and sallow, with apple as an unusual host.

4. *Depressaria aranella* (Schiff.)

The moths of this small *Tineid* were discovered in February hibernating in empty apple boxes in a warehouse at Herne Bay, Kent. This small moth should not be confused with the Codling Moth; it is not associated with fruit but hibernates in the adult state in outhouses and other suitable situations from September to March, the larva feeding on thistle, etc.

5. Cherry Fruit Moth (*Argyresthia curvella* Fab.)

This important cherry pest was prevalent near Faversham and Sittingbourne, the small, pale apple-green larvae being found in very young fruitlets during the first and second weeks of April. Early Rivers was more subject to attack than other varieties, but most commercial varieties were infested.

Because infested fruitlets fall to the ground shortly after petal-fall, even a serious infestation may be overlooked, and it is possible that the low yields of many orchards attributed to frosts or to poor pollination, may be caused by this moth.

Where this pest is known to persist growers should spray with a 7 per cent tar oil winter wash in December to kill the eggs. This spraying must be very thorough since the eggs are mainly deposited at the base of the buds and in crevices at the tips of the shoots. The trees should also be sprayed in the last week of March with 0·1 per cent DDT emulsion or miscible formulation to kill those larvae which hibernate in the winter. It should be noted that about 70 per cent over-winter in the egg state and the rest as larvae. When these recommendations are carried out efficiently little trouble will be caused by this pest.

6. Strawberry Tortrix (*Peronea comariana* Zell.)

The strawberry tortrix is common in some seasons in Kentish strawberry fields, causing considerable damage to fruitlets and foliage, while in others populations remain low and little harm results.

Early in April large numbers were observed in strawberry fields at Plaxtol, East Farleigh and Stone Street, and in the latter locality the damage was particularly severe. The larvae of this tortrix

are attacked by a small chalcid wasp, and this parasitic insect partly accounts for the low populations in some seasons.

The caterpillar of the first generation occurs in April and May and feeds on the leaves, flowers and fruit until about mid-June. The second brood feeds on the foliage in July and is fully fed a month later. The winter is spent in the egg state, the ova being laid at the base of the leaf stalks.

Both DDT and BHC, applied in late April, are effective against this pest, but these chemicals should not be used in strawberry fields where the chalcid parasite is prevalent.

7. Rosy Rustic (*Hydraecia micacea* Esq.)

The caterpillar of the Rosy Rustic moth was reported in July from Broomyard, Worcestershire, tunnelling into the roots of hop. It was also noted at Marden, Kent, where it caused considerable harm to young hop hills. The report from Kent is interesting because the hop grower considered the damage to be caused by the Hop Root Weevil (*Epipolaeus caliginosus* Fab.) which tunnels into the roots in a similar manner.

The Rosy Rustic caterpillar is pale, dull pink with a darker stripe along its back, dark spots along the sides and black spiracles; the head and first segment of body are yellowish-brown. Its usual host plants are dock and plantain and it tunnels in the roots from May to August. In certain seasons the larva can modify its natural mode of life and feed on hop.

The writer is indebted to Mr. K. J. Coghill for bringing the Worcestershire record to his notice.

8. Black Currant Sawfly (*Nematus olfaciens* Benson)

The Black Currant Sawfly was first recognized as a species distinct from the closely allied gooseberry sawflies five years ago, when specimens found feeding upon the foliage of black currant in Gloucestershire and Scotland were found to be an undescribed species. It has since been recorded from Lincolnshire and Essex and this year from Kent.

This sawfly has probably been established in Kent for many years, since a species noted on black currant was mistakenly regarded as the gooseberry species. The first authentic record, however, was from Ospringe, near Sittingbourne, Kent, in the third week of May, the larvae being found feeding on black currant foliage.

This pest is becoming more widespread in the south-east, East Anglia and the Midland counties, and currant growers who have not yet been troubled by this insect are advised to look out for it about the middle of May. At this period the young larvae are gregarious, and occur low down in the centre of the bushes. There are at least two generations each year.

9. Sphegid Wasp (*Trypoxylon attenuata* Smith)

Several larvae of a Sphegid wasp, an hymenopterous insect, were observed in November, 1956, hibernating in the hollowed out pith of raspberry stems at East Malling. It also occurs in the stems of blackberry. The larvae should not be confused with the over-wintering larvae of Dock Sawfly which also hibernates in such situations. The species is wholly beneficial since it feeds mainly on aphids with an occasional diet of small spiders. Under laboratory conditions the adults emerge about the third week of January.

The routine winter tipping and thinning of raspberry canes would prevent this beneficial insect from establishing itself in commercial raspberry fields.

10. Early records of fruit insects

The mild, warm weather during February, March and early April largely accounted for the very early emergence of several fruit insects. The males of the March Moth which usually start emerging early in March, were noted near Maidstone a month earlier than usual, the first record being on 3rd February. This species is readily attracted by light and numerous specimens were seen each night until the latter part of the month. Very few were seen in March, their usual flight period.

The Leaf-curling Plum Aphid had finished hatching by the end of March in plantations kept under observation at East and West Malling, and large populations were building-up by the end of April.

Another species of aphid which hatched out very early was the Oat-Apple Aphid. These were first detected on buds of Beauty of Bath on 3rd March at Sittingbourne. At Paddock Wood and East Malling hatching on Beauty of Bath started on 7th March. A week later the same aphid was common on the fruit buds of Gladstone and Cox, but was less common on Bramley's Seedling in the same orchard.

Owing to this very early hatch many growers started spraying about the third week of March.

Although this application proved effective, many more aphids hatched out during the Easter week-end and large populations built-up save where further control measures were carried out. In a spring when the Oat-Apple Aphid is abnormally abundant, one pre-blossom spray is not sufficient irrespective of the chemical used, the correct timing or indeed the mode of application. In such seasons some leaf-curl will occur even if two or more chemicals are applied pre-blossom for aphid control.

11. Potato Aphid (*Macrosiphum euphorbiae* Thos.)

The Potato Aphid was common in hop gardens near Maidstone, East Malling, West Farleigh and Rainham during the latter part of March and throughout April. The variety Fuggle was more heavily infested than others.

Many growers regarded this as an exceptionally early infestation of the Hop-Damson Aphid, and in consequence chemicals were applied a month earlier than usual.

At present there is no reason to suspect the Potato Aphid of causing any harm to the hop. It does not cause the shoots to ' bleed ' or stunt their growth, and it disperses to other hosts early in May. The Hop-Damson Aphid, which is the harmful species on hop, migrated to hop from sloe a little earlier than usual, but did not become established in Kentish hop gardens until after the Potato Aphid had dispersed.

12. Pear Sucker (*Psylla pyricola* Föer.)

Populations of the Pear Sucker fluctuate considerably from year to year. In 1957 abnormally high populations were noted throughout Kent, but the distribution of the insect was patchy. Severe infestations were also reported from Wisbech and the West Midlands, while some plantations in East Anglia were attacked for the first time. The varieties Conference, Laxtons, and Williams' were most affected ; Fertility seemed to be least susceptible of the commercial varieties.

The Pear Sucker started breeding very early in the year. Because of the earliness of the season, the eggs of the over-wintering generation were laid on the very young fruitlets, and only a few were deposited at the base of the flower buds which is the usual site of oviposition. Eggs were first seen the last week of March, first nymphs being observed on 9th April. By 17th April the immature stages were abundant in many plantations, and in one plantation at Faversham 211 eggs were laid on a single leaf. This was exceptional, but illustrates the severity of the infestations in some plantations of east Kent. Large populations of the second and third generations were common, especially where control measures were not carried out efficiently.

Summary

Brief notes are given of some interesting insects observed in 1957. Amongst the most important are the fungus beetle, *Endomychus coccineus* (L.), Coxcomb Prominent, Cherry Fruit Moth, Black Currant Sawfly, Sphegid Wasp and the Potato Aphid.

THE BIOLOGY OF THE BLACK CURRANT LEAF MIDGE *DASYNEURA TETENSI* (RÜBS.) IN RELATION TO THE PLANNING OF CONTROL MEASURES

By R. S. PITCHER

The Black Currant Leaf Midge, first recorded in Kent in 1928 (6), is now a common pest (2). The midge has from two to four generations a year, spending the egg and larval stages hidden in the leaves, the pupal stage in the soil, and the short adult life in flights in and around the bushes (3). The larvae feed on very young leaves at the tips of the shoots, distorting them and preventing normal expansion. This damage is often most severe, and certainly most important, on young nursery stock where it has the additional disadvantage of masking varietal characters and the symptoms of reversion. In fruiting plantations it is not a serious pest unless the leaf damage is very heavy, for unlike aphid or capsid damage, there is little risk of shoot distortion as neither the young wood nor the growing point itself is directly attacked. Nevertheless, the leaf-curling is unsightly and most growers wish to control this pest.

In the nursery, good control can usually be obtained by frequent applications of parathion or a similar insecticide. In the fruiting plantation the need to safeguard crop and consumer makes such practices undesirable and no entirely satisfactory alternative has yet been devised. The most common practice in recent years has been to spray the bushes with DDT, usually as an addition to the grape-stage lime-sulphur (4, 5), but the results, both in trials and in commerce, have been inconsistent. In the years 1947-53 attempts were made at East Malling to improve the performance of DDT sprays, largely without success, but as a result of concurrent biological observations several aspects of the life history which have an important bearing on control measures are now better understood. The data are given below in the hope that they may form the basis of a new approach to the problem of control and enable some of the newer insecticides to be used to best effect.

The emergence of midges of the first generation

Because of its long growing season and consequent midge-susceptibility the variety Goliath was used. The observations of five seasons, summarized in Fig. 1, show that the date of first emergence,

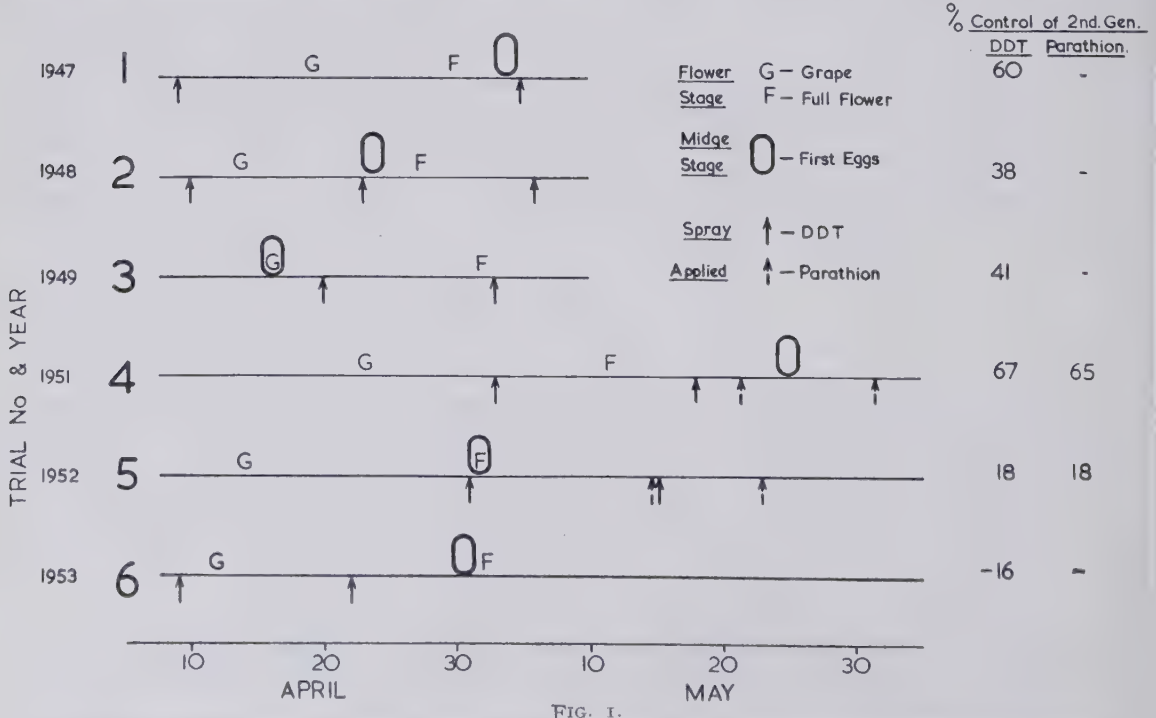

FIG. 1.

Timing of earliest midge oviposition relative to flower stage, with date and result of spray applications.

as judged by the first observed eggs, varied greatly from year to year and showed no consistent relationship with the blossom stage of the host plant. Thus, although the first eggs were usually laid within a few days of full flower, in 1949 they were laid about two weeks earlier (coinciding with the grape-stage) and in 1951 they did not appear until nearly two weeks after full flower. These variations have been recorded on one variety and within a restricted area ; it is likely that even greater variation would be found in commercial holdings composed of many varieties and in diverse situations. It is clear, therefore, that any timing based on blossom stage is liable to considerable error. The best compromise timing would be that of full-flower on Goliath, but risks to pollinating insects and perhaps to fruit-set make this undesirable. The blossom period can be avoided only at the cost of insecticidal efficiency, as the deposits of a pre-blossom spray will often become ineffective before emergence is complete, while a post-blossom spray will usually be too late and may contaminate the fruit.

The development of later generations

Observations were made on the later stages of the life-cycle during three seasons of contrasting weather. This was done by taking systematic samples of growing tips at about five-day intervals and counting the numbers of eggs and larvae present. The results are expressed graphically in Fig. 2,

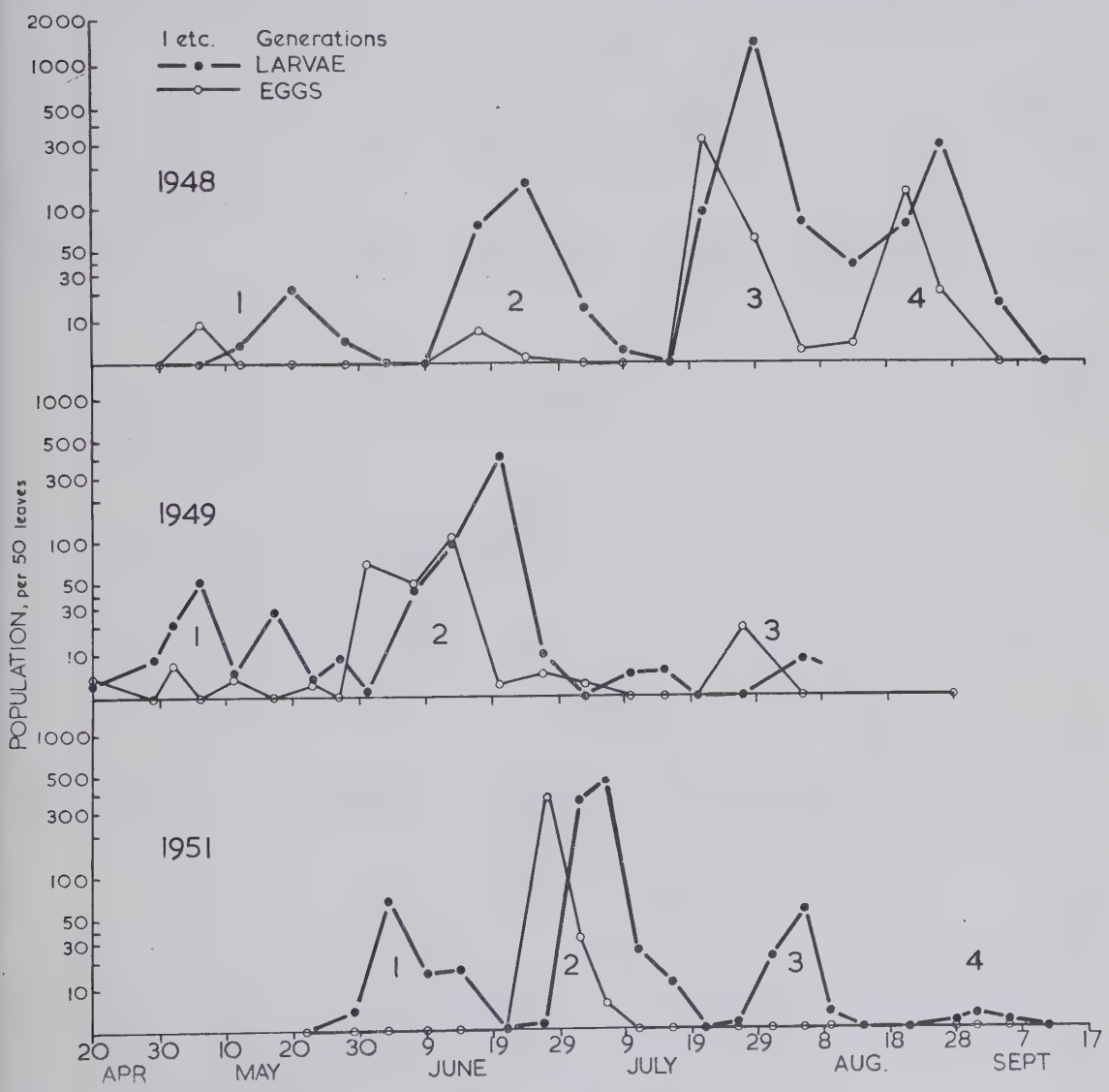

Fig. 2.

Midge population counts for three seasons, transformed to log (n + 10).

with populations plotted on a logarithmic scale to improve the separation of low readings. Because of the low numbers the data relating to the first generation must be treated with some reserve but those of later generations show plainly that the control problem expands rapidly unless the first generation is checked. Moreover, the pattern of the life-cycle is by no means the same from year to year. In the generally cool summer of 1948 a large third and an appreciable fourth generation developed, while in the hot dry summer of 1949 only a vestigial third, and no fourth generation occurred. In 1951 the first and second generations were retarded by a late spring and the third and fourth generations severely limited by a hot dry spell in late July. The effect of weather is twofold, partly an indirect effect exerted through the host plant and partly a direct effect on the soil. The former is probably the more important, as an ample supply of actively growing shoot tips is essential for the development of a sizeable third generation. Drought curtails shoot and leaf growth, so that few tips are available for egg-laying and many larvae are starved or desiccated for lack of suitable leaf cover. A hard dry soil crust directly impedes the movement of emerging midges and pupating larvae and may even dry out cocoons and kill their contents.

The planning of control measures

The possible approaches to the problems of chemical control of this midge may be grouped as follows.

Foliar sprays

If the vulnerable tip growth of rapidly extending shoots is to be protected throughout the danger period any non-systemic insecticide will need to be reapplied at regular intervals. Foliar sprays may be of three types :

Insecticidal.—Preventive measures against ovipositing midges require an insecticide that is both persistent and quick-acting.

Ovicidal.—Most of the eggs are hidden amongst tightly folded small leaves ; a substance with some penetrant power is therefore necessary.

Larvicidal.—Larvae protect themselves by curling the leaves, so that penetrant, or preferably systemic properties are necessary in a larvicide.

Soil treatments

These may be directed against either the cocooned stages or the emerging midges.

The cocooned stages.—Most of the thin-walled cocoons are made in the top inch of the soil. It is nevertheless difficult to reach and penetrate many with a liquid or to establish adequate concentrations of a fumigant at such shallow depths.

The emerging midges.—As the date of first emergence is largely unpredictable, a suitable insecticide must be persistent enough to be applied well in advance of the probable date and yet remain effective on the soil throughout the emergence period of two to three weeks. Newly emerged midges usually run about on the soil in search of a suitable spot to rest while they expand and dry their wings and body. Once dried, the midge is fully active and, in favourable conditions, mates and begins to lay eggs without delay. Experience with other species suggests that contacts between newly emerged midges and soil insecticides inhibit oviposition much more effectively than those between fully active midges and foliar insecticides (1, 7).

Trials of control measures

The timing of the DDT applications was arranged independently of the grape-stage lime-sulphur sprays and sought either to anticipate or to follow the deposition of the first eggs as closely as possible. Supplementary applications were made to some plots about 14 days later and in Trials 3-6 the soil around the bushes was also sprayed. A commercial wettable powder,* diluted to 0·1 per cent active ingredient, was used in all cases. In Trials 4 and 5 parathion was tested as an alternative to DDT. The first spray was applied as soon as leaf-curling was seen and in some plots a second spray was applied about 10 days later. A commercial emulsion,* diluted to 0·01 per cent active ingredient was used in each case.

Details of the timing of all sprays are given by the arrows in Fig. 1. The results were assessed by recording the proportion of curled shoots in the first and second generation and the best control of the second generation given by each material is tabulated at the right-hand side of Fig. 1. Only Trial 4 achieved the two-thirds reduction which was considered the minimum acceptable for commercial purposes. This occurred in an abnormal season which considerably upset the timing arrangements and

* For details of formulation see Pitcher (7)

was followed by a poor result in Trial 5 when timing was at an optimum. These and other results suggest that timing is not the most important factor and that some radical change of method is required.

Discussion

The erratic results of these trials and the inconsistent performance of commercial controls are probably due to the following factors.

(1) Difficulty in predicting or anticipating the emergence of midges of the first generation.

(2) Difficulty in providing and maintaining an effective deposit on foliage to inhibit egg-laying or to control eggs or larvae.

(3) The lack of suitable insecticides for use in either of these contexts.

Since this work was completed many new insecticides have become available, several of which promise to be more suitable than those tested. A safe but moderately persistent systemic insecticide would seem to offer the most practical and convenient means of control, but unless or until one such is available it may be well to bear the following points in mind when planning future trials.

(1) Foliar sprays tend to be unreliable, especially on fruiting bushes, and should be supplemented or supplanted by soil applications around the base of the bushes.

(2) The toxicant chosen should be persistent and yet able to quickly kill or disable newly-emerged midges. Alternatively, it could be a soil insecticide, effective against the cocooned stages, or, ideally, active in both these ways.

(3) Control measures should be put in hand *at least* a week in advance of the usual first emergence date of the midge (late April to early May in S.E. England) and repeated about two weeks later if required.

Acknowledgements

The author wishes to acknowledge suggestions and criticisms by Drs. A. M. Massee and G. H. L. Dicker and by Miss J. M. Buttfield (N.A.A.S.).

Summary

Biological observations on the Black Currant Leaf Midge, *Dasyneura tetensi* (Rübs.) extending over six seasons are described. The probable causes of the shortcomings of past control measures are discussed and suggestions made for the improvement of future control.

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ON THE APPLICATION OF THE CAPTURE-RECAPTURE METHOD TO AN ORCHARD POPULATION OF *BLEPHARIDOPTERUS ANGULATUS* (FALL.) (HEMIPTERA-HETEROPTERA, MIRIDAE)

By R. C. MUIR

The biology of *Blepharidopterus angulatus* (Fall.) is known from the work of Kullenberg(11) and Collyer(3, 4). The latter author also established its importance as a predator of orchard pests. Recent work on the interaction of this predator with its prey in orchards required methods applicable to the study of a changing population of active animals. One method widely used for such a population is known as the capture-recapture method, first used by Lincoln(15) for estimating wildfowl populations, and independently by Jackson(8) for determining the true density of tsetse flies. It involves releasing a known number of marked animals into an unknown population with which the marked animals freely mingle, and determining the proportion of marked individuals in a subsequent sample. The total number released divided by the proportion of marked ones subsequently found provides an estimate of the total population, if it has not changed in the interval between release and recapture through birth, death or dispersal. In practice the population is rarely static but, by adopting a programme of repeated catch and release, changes can be taken into account and estimates of population size and rates of change can be obtained(6-9). The precision of the estimates so obtained was discussed by Bailey(1) who developed maximum likelihood equations which gave unbiased estimates of population size, birth and death rates, along with their large sample variances, for the special case when sampling is confined to three occasions. All these authors counted each recapture as many times as it had been caught, but according to Leslie and Chitty(12) this method of grouping the observations results in some loss of information. They suggested an alternative method which takes account of the last previous capture, only, of any particular animal ; this method of grouping involves no loss of information and permits more accurate estimates to be made. They developed maximum likelihood equations for obtaining estimates and variances of the death rate and population size(13, 14). The solution of these equations involves an iterative method which would present a formidable task of computation if used for sampling chains as long as the ones contemplated in the present investigation. An alternative direct procedure has been devised by Mr. G. M. Jolly of this Station, which is equivalent in its efficiency to the maximum likehood method. The theory and computing details of this method will be discussed elsewhere. The purpose of this paper is to consider the application of the capture-recapture technique to an orchard population of adult *B. angulatus*, and to analyse the data by Jolly's direct method.

Technique of marking and the sampling procedure

The plot available for the study consisted of ten bush apple trees in two rows in the middle of a plot of approximately a thousand similar trees believed to be supporting similar densities of *B. angulatus*. A square plot would have been a more satisfactory arrangement.

On each sampling occasion the trees were tapped with a stick, one branch at a time, in such a manner that the insects were dislodged and fell into a tray held beneath(5). Specimens of *B. angulatus* were captured in 3 in. × 1 in. tubes and stored in the shade. The tapping was repeated until no more insects could be dislodged from the tree. Any other species of predatory insects and larval stages of *B. angulatus* were carefully returned to the tree and the tray vigorously shaken over the tree to return any small prey that might have been dislodged at the same time. The captures were taken to the laboratory for marking and identification.

Owing to their small size, about 4 mm. body length, these insects had to be marked under a low power binocular microscope. They were held in position by the low suction of a pipette connected to a water pump, a suitable pipette being made by grinding down the point of a coarse hypodermic needle. Once in position, three minute spots of artist's oil paint were applied to the dorsal surface of the thorax and wings using cabinet steel points mounted in match sticks. By using six colours, two at a time in thirteen positions, it was possible to give distinguishing marks in the form of a coded number(10) to all the insects caught. Because *B. angulatus* could get sufficient purchase on glass to resist the low suction used, it was usually necessary to anaesthetise the insects lightly with carbon dioxide in order to pick them up. In later work, an almost frictionless surface was obtained by coating

the inside of a petri dish with an unsintered dispersion of ' Fluon ' GP 1, polytetrafluoroethylene, PTFE. When specimens of *B. angulatus* were placed on such a surface, they could not obtain foothold and consequently were easily drawn onto the mouth of the sucking pipette without the use of an anaesthetic.

In addition to marking each specimen, its code number and sex, and the tree number from which it was taken, were recorded. Recaptures were also recorded by their code number and checked against the original entry to avoid gross errors. In the case of bad marking, and in a few cases of loss of a mark, the identity of the specimen could usually be established by back-reference and by eliminating the unlikely. The insects were finally returned to the trees from which they were taken ; dead, injured or sickly specimens, were recorded as such but not returned.

Sampling took place twice a week from the 18th August to 29th September 1955 the actual sampling being spread over two days to complete all ten trees. The weather throughout was ideal for the task, being dry and calm.

Preliminary examination of the basic assumptions

The underlying assumptions necessary for making satisfactory unbiased estimates of a population are that the marked animals mingle freely with the unmarked and are captured at random, that marking does not influence survival, that the different categories comprising the population, the sexes and the different age groups, are sampled in the proportion in which they occur, and finally that repeated handling should not influence chance of recapture. It is the purpose of this section to present what evidence exists relating to these assumptions.

Field experience of the activity of both marked and unmarked insects indicates that the former mingled readily with the population on the tree to which they were returned. Moreover, they were returned to all parts of the tree, and all available branches were sampled each time. It is most unlikely that marked individuals were consciously selected, because the marks were inconspicuous to the unaided eye, and the haste with which the insects were collected prevented scrutiny of the catch in the field.

No valid test of the influence of marking on survival is available for this population, but such a test would have required a separate experiment involving an isolated population in which there was no immigration. The marked individuals seemed to survive well as far as can be determined from the data and the distribution of recapture classes among the recaptures (Table III). Clearly marking did not grossly impair survival.

Influence of sex on chance of capture

A study of the number of recaptures (Table I), for those insects released on each occasion from 22nd August to 8th September inclusive, clearly indicates that males were less likely to be captured than females in every case examined. This is sufficient justification for separating the data into male and female components and conducting the analysis on each sex separately.

Influence of age on chance of recapture

Those insects released on any sampling date after the first will include insects marked for the first time and those already marked from previous releases. Since marking started before the entire population had reached the adult stage, insects marked for the first time will be younger on the average than those marked on earlier dates. Afterwards, when emergence is complete, both marked and unmarked proportions will tend to be of similar age. To make full use of the data, it is necessary to show that insects released on any day have an equal risk of recapture, irrespective of when they were first marked. To test this, females were grouped according to the dates on which they were marked, the numbers subsequently recaptured being compared with an expected value (Table II). As an example : on 22nd August 143 insects were released, 9 of which had been marked on the 19th August, and 5 were captured again, 134 were caught for the first time and marked on 22nd August and gave rise to 75 recaptures. This recapture frequency agrees closely with the values expected if the 9 from 19th and the 134 from 22nd were being caught with equal facility. These ' expected values ' are shown in brackets in Table II. Both in this Table, and also in the full field records, there was good agreement between the numbers expected and those observed. Thus, although a sample may consist of individuals marked on different dates and possibly of different mean age, these factors do not appear to affect the chances of subsequent recapture.

Influence of repeated handling on recapture

Random sampling will result in some individuals being caught more frequently than others so that it is necessary to test if repeated handling biases later recapture. The sample released on any

Table I

Average recaptures for marked male and female *B. angulatus*

Date	Sex	No. released	No. of recaptures	Average no. of recaptures
22nd Aug.	♂	156	61	0·39
	♀	143	129	0·90
25th Aug.	♂	173	46	0·27
	♀	164	131	0·80
29th Aug.	♂	190	43	0·23
	♀	202	132	0·65
1st Sept.	♂	171	39	0·23
	♀	214	198	0·93
5th Sept.	♂	148	30	0·20
	♀	207	177	0·86
8th Sept.	♂	93	11	0·12
	♀	243	176	0·72

Table II

Influence of age on chance of recapture in the female population of *B. angulatus*

Date of first capture	19th Aug.		22nd Aug.		29th Aug.		5th Sept.		12th Sept.		19th Sept.	
	No. released	No. recaptured	No. released	No. recaptured	No. released	No. recaptured	No. released	No. recaptured	No. released	No. recaptured	No. released	No. recaptured
19th Aug. ..	54	24	9	5 (5·0)	7	2 (2·5)	2	0 (0·9)	2	0 (1·1)	1	0 (0·5)
22nd Aug. ..			134	75 (74·9)	22	8 (7·7)	10	4 (4·9)	9	5 (5·1)	2	1 (0·9)
25th Aug. ..					26	11 (9·1)	15	6 (7·3)	6	1 (3·4)	4	3 (1·8)
29th Aug. ..					147	50 (52·0)	18	7 (8·8)	5	3 (2·8)	4	1 (1·8)
1st Sept. ..							32	23 (15·6)	20	10 (11·3)	13	9 (6·0)
5th Sept. ..							130	61 (63·4)	21	12 (11·9)	9	5 (4·1)
8th Sept. ..									23	13 (13·0)	20	8 (9·2)
12th Sept. ..									89	55 (50·4)	15	7 (6·9)
15th Sept. ..											16	10 (7·4)
19th Sept. ..											42	14 (19·3)
Total	54	24	143	80	202	71	207	101	175	99	126	58

Numbers in brackets are calculated values

one day was classified according to the number of times individuals had been captured ; again there was close agreement between the frequencies observed and those expected. This test, and the one given above, are not strictly independent, because those individuals recorded as being released from earlier dates have stood a greater chance of being handled than those from later releases. Similarly, those suffering most captures tend to be older than those caught least. If any trends were obvious it would be necessary to make these tests independent.

It would appear from this preliminary examination that samples released on any date were not giving rise to biased recaptures through being composed of individuals marked on different dates or caught a varying number of times and, as long as the analysis is conducted on the males and females separately, these groupings should not bias the estimates.

Presentation of the data

The scores of a capture-recapture programme can be arranged in some form of triangular array(6) ; one such lay-out is used here in the presentation of the female and male data (Table III).

The number caught at each sampling is entered in a column to the left of the Table along with the numbers released for that sampling occasion, differences between these two numbers represent accidental deaths and these are entered as superscripts to the numbers caught. The sampling occasions are arranged in step-like succession to the right of these two columns. Recaptures from previous releases are entered in the appropriate column for the row of the sampling occasion in which they were recaptured, the total in any row being the total number of recaptures for that sampling. Insects recaptured from any release are counted once only, and when caught they become members of a new release making no further contribution to the fate of the batch originally released. The female data for the 25th August (Table III) may be taken as an example. On that occasion, 169 females were caught of which five were accidentally killed and the remaining 164 were released. Among the 169 captures there were 37 bearing marks, three were caught for the first time since they were released on the 18th August and 34 had been released on the 22nd August. This method of assembling the data amounts to classifying the recaptures according to the time interval since the last capture and is Method B of Leslie and Chitty(12).

Estimates of population size and rates of population change

The results of the analysis of the data for both male and female populations are presented in Table IV. The ' wastage rate ' covers losses due to death or emigration, and the ' dilution rate ' includes all additions of unmarked insects whether due to emergence or immigration. The number of fifth (final) instar larvae observed from four trees, are also included in the Table to indicate the end of the larval period. Although the sampling was spread over two days only the first sampling date is given.

The female population was first estimated at 518·3 on the 22nd August ; the decimal point is retained to indicate an estimated value. The standard error of this estimate is $\pm 141 \cdot 8$, so that the actual population size is unlikely to exceed 801·9 or be less than 234·7. The population then increased to an estimated value of 1,080·1 within the limits 843·5 and 1,316·7 by 29th August, and declined to 463·1 by 26th September, the last estimate obtainable.

Larval stages were entirely absent after the 1st September. Presumably, these larvae died or emerged as adults ; in either case the female population could not receive further recruitment from the larval population after 1st September, and must be expected thereafter to decline through death, as shown by the estimated totals. The daily dilution rates from 22nd to 29th August are notably higher than they are afterwards. The mean dilution rate for 22nd, 25th and 29th August is 0·129, while that for the remainder is 0·034, a difference which is significant at the 1 per cent level. Presumably unmarked immigrants from other parts of the plot made a variable but continuous contribution to the dilution rate throughout the sampling period, a further contribution being due to females emerging during the period when larvae were present on the trees. The change from high to low dilution rate roughly coincided with the disappearance of larval stages.

In contrast to the dilution rates, the daily wastage rates fluctuate throughout the sampling period, but exhibit no particular trends in any part of the period.

The male population was about 622·3 at the beginning of the experiment and it fluctuated about the 1,130 to 1,150 level from 25th August until 12th September, when it began a rapid decline until males were hardly represented by 29th September. The higher values for wastage and dilution rates throughout the sampling period, and the fluctuating population estimates, all point to a tendency to greater dispersal among the males than is the case with the females. The data for the male population are meagre, however, compared with those for the female (Table III), and this results in poorer estimates.

Table III

Triangular lay-out for the data of the capture-recapture programme for female and male populations of *B. angulatus*. The recaptures are grouped according to the interval of time since they were last captured

Female population

Total caught	Total released	18th Aug.	22nd Aug.	25th Aug.	29th Aug.	1st Sept.	5th Sept.	8th Sept.	12th Sept.	15th Sept.	19th Sept.	22nd Sept.	26th Sept.	29th Sept.
54	54	18th Aug.												
146[3]	143	10[1]	22nd Aug.											
169[5]	164	3	34	25th Aug.										
209[7]	202	5	18[1]	33	29th Aug.									
220[6]	214	2	8	13	30[1]	1st Sept.								
209[2]	207	2	4	8	20	43[1]	5th Sept.							
250[7]	243	1	6	5	10	34[2]	56[1]	8th Sept.						
176[1]	175	0	4	0	3	14	19	46	12th Sept.					
172[3]	169	0	2	4	2	11	12	28[1]	51	15th Sept.				
127[1]	126	0	0	1	2	3	5	17	22	34	19th Sept.			
123[3]	120	1[1]	2	3	1	0	4	8	12	16	30	22nd Sept.		
120	120	0	1	3	1	1	2	7	4	11	16	26	26th Sept.	
142	142	0	1	0	2	3	3	2	10	9	12	18	35	29th Sept.

Male population

Total caught	Total released	18th Aug.	22nd Aug.	25th Aug.	29th Aug.	1st Sept.	5th Sept.	8th Sept.	12th Sept.	15th Sept.	19th Sept.	22nd Sept.	26th Sept.	29th Sept.
134	134	18th Aug.												
166[10]	156	19	22nd Aug.											
175[3]	173	10	24	25th Aug.										
200[10]	190	6	8	24[2]	29th Aug.									
181[10]	171	1	9[2]	2	23	1st Sept.								
155[7]	148	0	3	5	6	15	5th Sept.							
97[4]	93	0	1	4	1	7	17	8th Sept.						
86[2]	84	0	0	0	4	2	5	4	12th Sept.					
49[1]	48	0	1	0	0	3	2	1	6[1]	15th Sept.				
25[1]	24	1	1	0	0	2	0	3	2	3	19th Sept.			
25[1]	24	0	0	0	1	0	0	1	1	2	3[1]	22nd Sept.		
18[1]	17	0	1	0	0	0	0	0	0	1	1	0	26th Sept.	
9	9	0	0	0	0	0	1	0	0	0	1	0	0	29th Sept.

Superscripts denote the numbers accidentally killed

Table IV

Population estimates, daily wastage-rates and daily dilution-rates for female and male populations of *B. angulatus*

Date	Female population			Fifth instar larvae from four trees	Male population		
	Population estimates	Daily wastage rate	Daily dilution rate		Population estimates	Daily wastage rate	Daily dilution rate
18th August ..	—	0·105±0·019	—	88	—	0·158±0·038	—
22nd August ..	518·3±141·8	−0·018±0·018	0·132±0·099	39	622·3±266·3	−0·020±0·050	0·181±0·086
25th August ..	813·4±110·2	0·013±0·014	0·084±0·040	15	1,139·0±204·7	0·128±0·043	0·127±0·050
29th August ..	1,080·1±118·3	0·191±0·018	0·172±0·048	5	1,136·5±214·2	0·169±0·062	0·172±0·066
1st September ..	1,019·9±114·0	0·044±0·013	0·020±0·033	2	1,148·2±245·3	0·129±0·052	0·128±0·053
5th September ..	925·2± 82·6	0·084±0·018	0·042±0·033	0	1,140·0±270·2	0·041±0·099	−0·020±0·071
8th September ..	816·8± 60·6	0·105±0·015	0·055±0·023	0	948·4±290·0	0·125±0·092	0·192±0·064
12th September	667·7± 55·9	0·008±0·025	−0·009±0·028	0	1,238·8±443·2	0·285±0·138	−0·048±0·103
15th September	632·9± 50·5	0·095±0·024	0·026±0·018	0	460·3±188·8	0·040±0·121	−0·085±0·072
19th September	480·1± 45·9	0·043±0·041	0·060±0·027	0	102·8± 45·3		0·208±0·110
22nd September	505·6± 60·3	0·064±0·041	0·042±0·022	0	—		
26th September	463·1± 69·6		0·017±0·028	0	—		
29th September	—			0	—		

These estimates were all obtained by Mr. Jolly's method which gives independent estimates of population size so that comparisons of these values present no difficulty. Alternate estimates of wastage and dilution rates are also independent, but adjacent ones are not, so that a negative covariance must be used when comparing adjacent values. In the comparison of the mean female dilution rate from 22nd-29th August with that from 1st-26th September the covariance was taken into account.

Discussion

A population of active individuals, which is changing through birth, death, and dispersal, can be studied by the capture-recapture method, provided the individuals can be marked in such a way that their chance of further capture is unaltered, and this method is applicable to the population of *B. angulatus* investigated. The population estimates so obtained refer to those insects available for sampling on the ten trees sampled, and the dilution rate refers to the combined effect of emergence and immigration. Only when emergence is known to have finished through the absence of larvae on the trees is the dilution rate a measure of immigration. The wastage rate is a combined loss by death and emigration ; this is unfortunate since the death rate is of such biological importance. In the case of an isolated population where dispersal is negligible the capture-recapture method provides direct information on emergence and death, and it is in such a context that the method is of importance to the student of animal populations. The present problem, however, is to study the response of a predator population to different levels of prey abundance, and involves open populations free to move to different levels of prey density. If the limitations of the method are accepted, and it proves possible to mark two populations (in practice this merely involves distributing the number marked in the time available amongst two populations) the method should provide a valuable means of investigation. For the comparison of two such populations, it is essential to know the precision of the estimates and this has been met adequately by the improved method of analysis used here.

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Summary

An orchard population of *B. angulatus* was studied by means of the capture-recapture method. The method of marking is described and the marking programme outlined. The data are analysed to examine the influence of sex, age and recapture history, on survival. Only the two sexes showed sufficient differential survival to justify separate treatment.

Estimates of population, daily dilution and wastage rates, were obtained by a new method of analysis devised by Mr. G. M. Jolly.

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PLANT PROTECTIVE CHEMISTRY

FURTHER PHYTOTOXICITY STUDIES WITH PHENYLMERCURIC CHLORIDE ON CONFERENCE PEAR

By A. H. M. KIRBY and MARGERY BENNETT

The fungicide, phenylmercuric chloride, PMC, has been reported to cause damage to leaves and loss of chlorophyll (1). Further trials were carried out in 1952-54 to study the influence of season, timing and concentration on this phytotoxic effect, and in 1953 and 1954 to ascertain the effect on cropping.

Layout and materials

The plot used in each year consisted of thirty trees of Conference on Quince A, planted in the winter of 1949-50 at 8×4 ft. These provided five single-tree replicates of six treatments which were re-allocated each year within each replicate block, in such a way as to make comparison of treatments independent of those in preceding years. One treatment was always an unsprayed control, and another was common to all three years.

Only one mercurial was used, viz, a commercial preparation of phenylmercuric chloride dispersed on china clay to give a wettable powder containing 2·5 per cent PMC. In the third season, a programme based on sulphur fungicides was included for comparison.

Treatments

Applications in each year were made at one or more of the normal spraying periods for control of scab on pears, the maximum being two applications pre-blossom and two post-blossom. An application of PMC at the standard rate of 0·005 per cent (2 lb. of the wettable powder per 100 gal. wash) on these four occasions constituted a reference treatment common to each year. The treatments and dates of application for the three years are given in Table I.

The following issues were considered :

(*a*) The seasonal variation in the effects caused by routine application of PMC at 0·005 per cent.

(*b*) The effects due to pre-blossom as compared with post-blossom application of PMC at the same concentration as in (*a*).

(*c*) The effects due to the application of the same *total* amount of PMC as in (*a*) but in two pre-blossom or in two post-blossom doses ; the latter treatment was repeated in the second year.

(*d*) The effects due to a higher level of PMC (0·01 per cent) pre-blossom only, in association with the standard-rate post-blossom, and to the higher rate on all four occasions.

(*e*) The effects due to half the standard rate of PMC applied on all four occasions.

(*f*) The effects of a single application of PMC at the standard rate at either white-bud or petal-fall.

(*g*) The effects of a schedule based on sulphur as compared with the various PMC schedules and with unsprayed controls.

At no time was Pear Scab seen and the unsprayed trees therefore functioned as genuine controls.

Applications were made with a twin-nozzle lance from a small, self-propelled machine giving a maximum of 110 lb. pressure per sq. in.

Damage to leaves

Trees sprayed only pre-blossom showed no damage even when, as in 1952, PMC was applied twice at 0·01 per cent. On the other hand, all trees receiving post-blossom applications of PMC, with or without pre-blossom applications and even those receiving a single dose at petal-fall, developed characteristic leaf-damage sooner or later.

In 1952, pale spots on the upper surface, associated with browning around deposits on the lower surface, appeared within three days after the petal-fall application of PMC at 0·01 per cent (treatment 52/5) ; these symptoms were seen again in 1953 in treatment 53/4, but took a fortnight to develop, being preceded by wrinkling of the leaves a week after spraying. Where lower concentrations were used in the 1952 trial (treatments 52/1 and 52/3), the pale spots appeared only after the second post-blossom application. Wrinkling appeared in 1953 on the higher-rate treatments (53/3 and 53/4)

TABLE I

TREATMENTS AND DATES OF APPLICATION FOR THE THREE YEARS, 1952-54

Treatment No.	Percentage concentration of PMC applied on :			
	8.iv.52	16.iv.52	2.v.52	14.v.52
52/1	0·005	0·005	0·005	0·005
2	0·005	0·005	none	none
3	none	none	0·005	0·005
4	0·01	0·01	none	none
5	none	none	0·01	0·01
6	Unsprayed control			
	31.iii.53	16.iv.53	4.v.53	20.v.53
53/1	0·005	0·005	0·005	0·005
2	0·01	0·01	0·005	0·005
3	0·01	0·01	0·01	0·01
4	none	none	0·01	0·01
5	Unsprayed control			
	5.iv.54	15.iv.54	10.v.54	26.v.54
54/1	0·005	0·005	0·005	0·005
2	0·0025	0·0025	0·0025	0·0025
3	none	0·005	none	none
4	none	none	0·005	none
5	Unsprayed control			
6	Lime-sulphur 2·5%	Lime-sulphur 2%	Dispersible sulphur 0·3% S	Dispersible sulphur 0·3% S

after 5 days, but on the lower-rate treatments (53/1 and 53/2) after 8 days ; slight leaf-fall had occurred by the 13th May, and chlorotic spotting by the 20th, on all sprayed trees, but not on unsprayed trees. Similar results were obtained in 1954, the standard treatment (54/1) leading to chlorotic spotting by two weeks after the petal-fall application, and the half-strength treatment (54/2) only after the last application. The single application at white-bud (54/3) caused no visible leaf damage, but that at petal-fall (54/4) acted as 54/1, causing pale spots in two weeks. No leaf damage was seen on trees receiving the sulphur programme or on those left unsprayed.

Damage to crop

Sufficient fruit-buds were present in 1953 and 1954 to allow records to be taken of fruit-set and crop. No effect on fruit-bud initiation was found from any treatment in the three trials reported here, although evidence of such an effect has since been obtained on this variety.

However, all PMC treatments in 1953 severely reduced fruit-set (recorded on 19th May), as compared with the unsprayed trees (Table II), and this effect was evident in the records of crops picked on 9th September. These reductions were highly significant ($P<0·001$), but there were no differences between the various spray treatments. In 1954, no significant differences appeared when

TABLE II

PERCENTAGE FRUIT SET AND NUMBER OF FRUITS IN 1953

Treatment	No. of fruit set per 100 fruit buds 19.v.53	No. of picked fruits per tree
53/1	32·6	5
2	28·9	3
3	14·2	1
4	25·2	2
5	171·4	31
L.S.D. ($P<0·001$)	36·2	10

fruit-set was recorded, but a record taken on the 18th June, fully three weeks after the final application, showed significantly fewer fruits on treatments 54/1 and 54/2 than on the unsprayed trees (54/5), or on those trees sprayed with PMC once only (54/3 and 54/4, Table III). Trees receiving the sulphur schedule did not set significantly fewer fruits than the unsprayed trees, but nevertheless not significantly more than trees receiving PMC four times. The final weight of crop picked on 14th September, gave a similar picture.

TABLE III

PERCENTAGE FRUIT SET AND CROP WEIGHT IN 1954

Treatment	No. of fruit set per 100 fruit buds 18.vi.54	Crop weight (lb.) per tree
54/2	10·4	1·4
1	9·8	2·3
6	20·5	5·2
3	38·9	6·0
4	29·4	8·0
5	31·1	7·1
L.S.D. (P<0·01)	*	3·7

* These percentages were transformed to angles of equal information and the brackets are based on the significant difference required for the transformed values.

Discussion

The records of crops, as well as earlier post-blossom records, in 1953 and 1954 show that the damage caused by applications of sprays containing phenylmercuric chloride (PMC) to Conference pear trees is not confined to the leaves. It has been confirmed over the three years 1952-4, that chlorotic patches, associated with spray deposits, develop on sprayed leaves, as was observed in 1951 (1). Wrinkling is also caused and may precede the appearance of the pale spots. The time required for the appearance of symptoms seems to vary with the season, the concentration of PMC applied, and the timing of the sprays. No visible damage was caused by a single application of 0·005 per cent PMC at white-bud in 1954, but a similar application at petal-fall evoked typical damage.

Although fruit records were possible in only two years, it is clear that four applications, two pre- and two post-blossom, even at the low rate of 0·0025 per cent PMC, can cause a severe loss of crop on Conference. A single application at the normal rate, 0·005 per cent PMC, either at white-bud or petal-fall in 1954, did not reduce the crop significantly. On the other hand, two post-blossom applications of 0·01 per cent PMC caused a significant loss of crop in 1953.

A sulphur schedule, based on lime-sulphur pre-blossom and dispersible (elemental) sulphur post-blossom, did not cause a significant reduction of crop in 1954, but the effects of such a schedule require further investigation.

The results suggest that phenylmercuric chloride may be expected to cause reduction in leaf efficiency and fruit yield in the variety Conference, beyond anything likely to result from the use of lime-sulphur/dispersible sulphur programmes.

In view of the sharp seasonal difference recorded on an apple variety, Cox's Orange Pippin, by Shaw and Moore (2), the weather conditions following post-blossom applications in these trials were examined. The maximum temperatures and rainfall for the week following petal-fall and fruitlet application in each year are given in Fig. 1 ; it is assumed that the absorption of mercury by the tree will fall off more or less asymptotically so that the first few days after an application will be most important.

Shaw and Moore suggested that damage to apple by PMC was accentuated by wet weather, there being much less damage in the drier year. But, on pears, damage occurred in the week following either application in 1953 although the weather was very dry. On the other hand, while hot spells followed fruitlet application in all three years, only in 1954 was there hot weather following petal-fall application. Yet it was in 1953 that damage so clearly followed the petal-fall spray. Thus it is difficult to relate the damage caused to pears by PMC either to wet weather or to hot, dry weather ; indeed, it would appear that there is always a risk of damage to Conference pear by post-blossom applications of PMC.

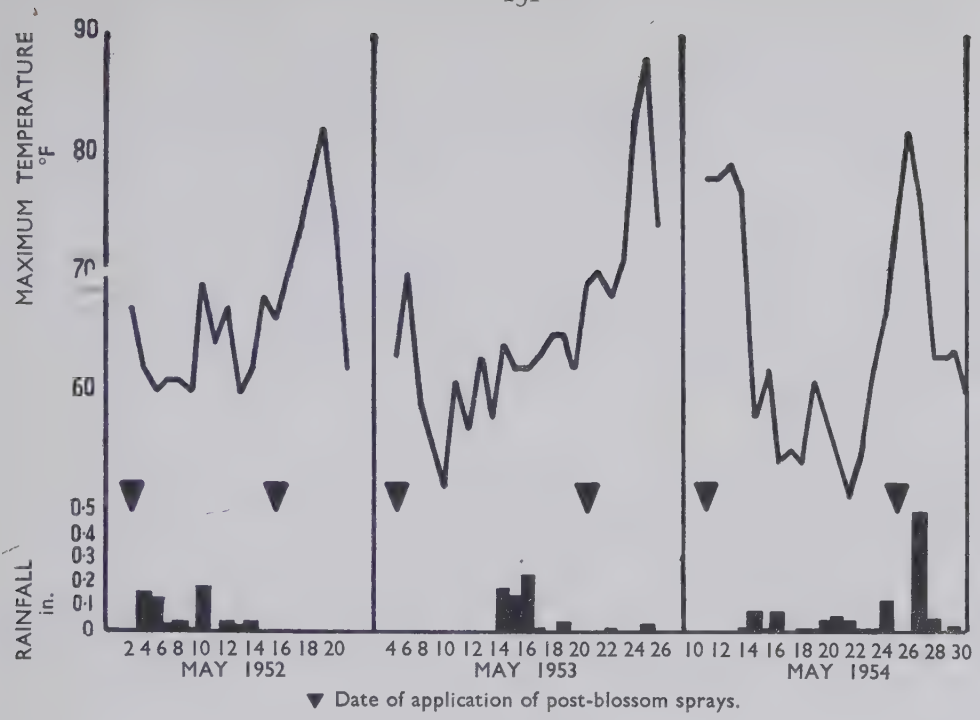

FIG. 1

Maximum temperatures and rainfall in relation to post-blossom applications of PMC.

Summary

Spray schedules, based on a wettable powder containing phenylmercuric chloride (PMC), have been applied in three seasons to young trees of Conference pear.

Leaf damage was caused by complete schedules (two pre- and two post-blossom applications) at 0·01, 0·005 or 0·0025 per cent PMC, and even by a single application at 0·005 per cent at petal-fall.

Reduced fruit-set and severe loss of picked crop were caused by the full schedules, and by two applications at 0·01 per cent PMC applied post-blossom only.

Unlike damage by this fungicide to apple, damage to pear does not appear to depend upon wet weather following application, nor is it confined to hot, dry weather, but is likely to follow post-blossom application in any season.

The lower crop weight recorded from trees given a full sulphur programme (in one year only) was non-significant.

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PHYTOTOXICITY TRIALS WITH ACARICIDES ON BLACK CURRANT AND PLUM

By A. H. M. KIRBY and MARGERY BENNETT

A number of new acaricides have come into use in recent years and it was considered desirable to see whether some of them could be used safely on black currant or plum. No biological information regarding efficacy against Big Bud Mite on black currant or Fruit Tree Red Spider Mite on plum was available when the trials were commenced, but the latter pest had been shown to be controlled by such materials on apple.

Trials on black currant

Layout, materials and methods

Thirty-six bushes of each of the varieties, Boskoop Giant and Wellington XXX, were planted in the autumn of 1949, in groups of three pairs of one variety alternating with the other. The unit was thus a pair of bushes of one variety, and three replicates of six treatments were available for each variety. Trials began in 1953 when the bushes were 5 years old.

In all three seasons, 1953-5, one treatment was an unsprayed control. Acaricides were applied once only in each season, namely at the grape-stage, the dates being 31st March 1953, 5th April 1954, and 12th April 1955.

The standard treatment, lime-sulphur at 2 per cent, was included as one treatment in each year, and two other treatments were common to all three years, namely, fenson and chlorfenson at 0·1 per cent in both cases. In 1953, the other two treatments were diphenyl sulphone at 0·2 per cent, and malathion at 0·09 per cent ; in 1954, diphenyl sulphone at 0·2 per cent, and chlorbenside at 0·1 per cent ; and in 1955, chlorobenzilate at 0·1 per cent, and chlorbenside at 0·1 per cent. Malathion was obtained as a 90 per cent pure commercial material, and was formulated with Lissapol NX, diacetone alcohol and Aerosol OT, to give final concentrations of 0·2, 0·2, and 0·02 per cent, respectively. Chlorobenzilate was also obtained as a 90 per cent pure commercial sample. The melting-points of the other acaricides were as follows : diphenyl sulphone, 127·5-128·5° C. ; fenson, 54-6° C. (1953), and 59-60·5° C. (1954-5) ; chlorfenson, 80-81° C. (1953), 83° C. (1954) and 84° C. (1955) ; chlorbenside, 71-72° C. Chlorobenzilate and these solid acaricides were formulated with diacetone alcohol, MB320, and Aerosol OT, to give final concentrations of 2, 0·05, and 0·01 per cent, respectively.

Applications were made by hand-lance to run-off, using a small machine giving 100 lb. per sq. in. pressure in 1953 and 1954, and a larger machine giving 200 lb. per sq. in. in 1955.

Results

Some marginal scorch developed on leaves sprayed with lime-sulphur in 1954 and 1955, but no leaf damage was seen on any bushes of either variety receiving the other acaricides.

No influence on blossom or fruit-set was detected on either variety, and no significant differences in crop on Wellington XXX appeared in any season, nor on Boskoop Giant in 1953 or 1955 (Table I).

TABLE I

AVERAGE CROPS PER BUSH IN ALL YEARS FOR BOTH VARIETIES

	Wellington XXX (lb.)	Boskoop Giant (lb.)
1953	5·9	1·8
1954	6·4	(See Table II)
1955	13·3	5·6

On the latter variety, however, in 1954 significantly larger crops were obtained from bushes sprayed with lime-sulphur or with chlorfenson, the remaining treatments not differing from the unsprayed control (Table II).

TABLE II

CROP WEIGHTS FOR 1954 TRIAL : VARIETY, BOSKOOP GIANT

Treatment	Crop weight (lb.)
1. Unsprayed	3·3
2. Fenson, 0·1%	3·0
3. Diphenyl sulphone, 0·2% ..	3·4
4. Chlorbenside, 0·1%	4·3
5. Chlorfenson, 0·1%	5·7
6. Lime-sulphur, 2%	5·7
	Sig. diff. = 1·5 (P<0·01)

Trial on plum

Layout, materials and methods

A block of 120 trees each of Victoria and Early Laxton, both on Common Plum, were planted in the autumn of 1951, in alternate rows, 8 trees to a row. This provided 20 plots containing 6 trees of each variety. In 1954, when only 4 treatments were used, there were therefore 5 replicates, but in 1955 and 1956, when an unsprayed treatment was added, only 4 replicates were possible. The trees were thinned in winter 1955-6, by removing alternate diagonal rows, leaving only 3 trees of each variety per plot for the 1956 season.

In all three seasons, the four acaricide treatments were :

A. Mid-May (Plum Sawfly timing)
   1. Chlorfenson, 0·05 per cent
   2. Chlorbenside, 0·05 ,, ,,

B. June (Plum Maggot timing)
   1. Chlorfenson, 0·05 per cent
   2. Chlorbenside, 0·05 ,, ,,

These chemicals were applied as commercial wettable powders, the chlorfenson preparation containing 50 per cent active ingredient, and the other containing 20 per cent chlorbenside. Applications were made as follows :

1954 17th May and 15th June ;
1955 19th May and 14th June ;
1956 17th May and 14th June.

Sprays were applied by hand-lance to run-off, using a pressure of approximately 200 lb. per sq. in. All trees received Bordeaux mixture (4 : 6 : 100) in May 1954, and a copper oxychloride preparation in May 1956 ; in both years copper damage developed on leaves and fruit.

Results

No leaf damage attributable to the acaricide sprays developed on either variety ; nor was any fruit damage observed. Crops were always heavier on the Victoria trees than on Early Laxton (Table III) but no significant differences in size of fruits or weight of crop appeared in any year among the acaricide treatments nor from the unsprayed controls in the two years when these were included.

No records of attack by the Fruit Tree Red Spider Mite were taken, but unsprayed trees became bronzed in July 1955 ; chlorfenson was applied late that month over the entire block and further damage prevented.

TABLE III

CROP WEIGHTS AND FRUIT SIZES IN PLUM TRIAL

	Victoria		Early Laxton	
	Crop wt. (lb.)	No. of fruit/lb.	Crop wt. (lb.)	No. of fruit/lb.
1954	2·7	11	0·6	5
1955	34·1	10	6·7	18
1956	36·1	15	17·5	38

Summary

Two black currant varieties, Boskoop Giant and Wellington XXX, were sprayed at the grape-stage with the following acaricides : lime-sulphur, 2 per cent (3 years) ; fenson, 0·1 per cent (3 years) ; chlorfenson, 0·1 per cent (3 years) ; diphenyl sulphone, 0·2 per cent (2 years) ; chlorbenside, 0·1 per cent (2 years) ; chlorobenzilate, 0·1 per cent (1 year) ; malathion, 0·09 per cent (1 year). Apart from marginal scorch due to lime-sulphur in two years, no damage to leaf or fruit was seen. No crop losses were recorded, but in one year (1954) there were significantly larger crops on bushes receiving lime-sulphur or chlorfenson.

Two plum varieties, Victoria and Early Laxton, were sprayed in three years with chlorfenson or chlorbenside, at 0·05 per cent, either at the time when sprays would be applied for control of Plum Sawfly (mid-May) or of Plum Maggot (mid-June). No damage to leaf or fruit attributable to the acaricides occurred, and crops did not differ from those on the unsprayed control trees.

Part IV

BULLETINS FOR FRUITGROWERS

SOIL MANAGEMENT EFFECTS ON VARIOUS SOIL PROPERTIES AND THEIR POSSIBLE INFLUENCE ON FRUIT CROPS

By J. E. GOODE and G. C. WHITE

Already a great deal is known of the effects of different soil management treatments on fruit crop production and quality. Recommendations have been made, and widely adopted, but under certain conditions growers are frequently in doubt as to the best practice to adopt. Knowing the effects of a soil management practice on the various soil properties may help a grower to decide on the right cultural treatment for his orchard soil. A study has been made of the effects of three methods of soil management on the following soil factors : moisture conditions, organic matter content, resistance of soil crumbs to slaking on wetting, nitrogen content, and availability of the nutrients potassium, phosphorus, and magnesium. A research paper giving results of this study has appeared on p. 113 of this report. The purpose of this bulletin is to consider the possible influence of these effects on fruit crops.

The cultural practices studied were summer cultivation with autumn weeds, a permanent sward and a permanent straw mulch. Treatments were started in spring 1951 and continued until October 1956. The soil was a well-drained fine sandy loam of good depth (3-4 ft.) overlying free-draining calcareous sandstone of the Hythe Beds.

Cultivation was by hand-digging and hoeing, and was therefore much less drastic mechanically than normal orchard cultivations. The sward consisted of S23 perennial ryegrass and Kent wild white clover sown at rates of 16 lb. and 2 lb. per acre respectively. The sward was mown when the herbage reached an average height of 4 in. Growth was permitted during late summer and a final cut was given in October. Cutting was done on about twelve occasions during each season and clippings were left on the swards to decompose. The mulch consisted of an initial application of wheat straw at a rate equivalent to 8 tons per acre and then of subsequent annual applications at a rate equivalent to 4 tons per acre. The mulched soil received no cultivation and the few weeds that appeared were hand-pulled.

The study was made in the absence of manures, fertilizers or crops, hence any changes in the various soil properties could be regarded as soil management effects.

Clean cultivation

Summer cultivation over five growing seasons caused a serious deterioration in the chemical and physical properties of the soil. The nutrient retentive capacity appeared to decline, since there was evidence of potassium leaching and a reduction in available phosphorus and magnesium. Organic matter and total nitrogen declined and were much less than under the sward. Laboratory tests of soil crumb stability to wetting showed that the crumb structure of the cultivated soil was quite unstable. The ready dispersal of soil particles gave rise to a surface crust, only too familiar on cultivated soils, which in turn imparted a low infiltration capacity. This was demonstrated forcibly in the field by water standing on the surface of the soil after heavy or persistent rainfall. In the wet condition there must inevitably have been a general impenetrability to air.

Soil moisture tensiometers at a depth of 12 in. gave a continuous record of soil moisture conditions. It was noticed that summer rainfalls seldom wetted the soil to this depth, so that many fruit crop roots in a cultivated soil would be largely deprived of the benefit of summer rains because of high evaporation losses from the surface and because cultivation operations prevent surface rooting. At least $\frac{1}{2}$-$\frac{3}{4}$ in. of continuous rain was required to rewet the dried cultivated layer and only continuous rain in excess of this amount could be considered useful for root zone replenishment. However, the actual reserves

of moisture present in the soil at the start of the growing season were relatively well conserved compared with conditions under the sward. Maximum losses from these reserves in the cultivated soil were generally about 1½ in. but in the drought year of 1952 a soil moisture deficit of 2 in. was sustained. Though the soil moisture reserves would be available for crop use under cultivated conditions, replenishment by summer rainfall would be meagre. In addition, deterioration in other soil factors would almost certainly affect the vigour or condition of the crop and so could be expected to reduce its ability to extract moisture from the soil.

A crop needs soil conditions in which root extension and ramification can proceed unchecked if it is to avail itself fully of the moisture reserves or nutrients in the soil. Soil dispersion will inevitably lead to the filling of the larger soil cavities and may result in pores too small for root penetration. Surface root damage is known to occur during cultivation and so root exploitation of the soil volume will tend to become less and less efficient. Under such conditions the utilization of nutrients and water by a crop may become progressively more dependent on the area of absorbing root surface than on the chemical and physical availability of the nutrients and water respectively ; thus deficiency and drought symptoms may appear in a crop when the soil may still have adequate available resources of nutrients and water.

There does not seem to be a practical alternative to organic matter for maintaining the soil in a favourable condition both in respect of nutrient availability and for a root distribution and activity adequate to meet the requirements of a crop. It is probably of little import whether the organic matter is supplied as bulky manures and organic residues and incorporated into the soil or by growing a sward mixture. However, the difficulty of finding an outside source of organic material, in sufficient quantity, was the reason that cover crops were recommended for orchards.

Sward

After five years the organic matter content in the first 12 in. of soil was nearly half as great again under the sward as that in the cultivated soil. This very marked difference after so short a time was due partly to a build-up under the sward and partly to depletion under cultivation. The stability tests of the soil crumbs showed that there was a more stable structure under the sward than in either the cultivated or mulched soil. In the field it was noticed that the soil under the sward was much more friable than under either of the other two cultural practices. This condition may be directly related to the higher organic matter content and the biological activity associated with grass roots.

Nutritional conditions did not change appreciably under the sward. A decrease in the content of available phosphorus in the 0-6 in. soil depth was largely compensated for by an increased content in the 6-12 in. depth. This interesting feature of the sward management appears to be a function of grass root activity rather than an effect of the surface additions of organic material in the form of grass clippings. It is perhaps of importance in the grassed orchard since the improvement in phosphorus availability occurs at a depth where tree root density and activity are probably at a maximum. Available potassium appeared not to change whilst available magnesium was depressed only slightly, thus it appears that grass grown in conjunction with an orchard crop would not strictly compete for available nutrients (except for a short establishment period) but would serve to maintain a balanced nutrient supply for the use of the orchard crop. The exception to this is nitrogen in the form that the crop can use, for though there is a return of nitrogenous material to the soil from the sward, nitrification of this material probably proceeds too slowly and spasmodically, due to adverse moisture conditions, to provide mineralized nitrogen (i.e. nitrogen the crop can absorb) much in excess of the needs of the sward.

In all years (1952-5) depletion of the available reserves of moisture by the sward was high. Full and rapid utilization of moisture in the 0-18 in. depth of soil occurred, whilst drying proceeded more slowly in the deeper soil layers. In 1952, the entire content of available moisture was used from 3 ft. of soil, equivalent to 5·7 in. of water ; in 1953, 5 in. of the available reserves were used, whilst 4 in. and 4·5 in. were used in 1954 and 1955 respectively. Soil moisture loss was low in 1954 and 4 in. probably represented the maximum possible loss from the sward but in 1953 and 1955 higher losses were to have been expected and from climatic data 1955 losses should have been greater than 1953. Hence, it seems that the sward was exploiting the soil moisture reserves less fully and rapidly as it aged.

Close and frequent mowing has been shown to reduce the depth of soil from which moisture can readily be extracted by grass roots, but this effect of an ageing sward is additional and whether the effect would be similar for long grass is not known. It is considered, however, that the frequent and close cutting management of the sward largely contributed towards a progressive reduction in the density of the deeper roots of the sward, an effect probably helped by the absence of nitrogenous fertilizer.

The major disadvantage of the sward system of soil management for fruit crops is undoubtedly the very heavy demands it makes on the soil moisture ; but there are compensating factors, not immediately obvious, whose cumulative effects may amount to quite an appreciable influence on the water available to the fruit crop. These ' compensating factors ' are :

(1) Under a sward the topsoil is available for and is used by fruit crop roots, whereas under clean cultivation the surface roots are deprived of the top 4 in. of soil in which the amount of available moisture may be between 0·5 in. and 0·8 in. at field capacity.

(2) The stable structure of the soil under the sward permits ready in-take of rainfall to the roots developed near the surface.

(3) The absence of root damage under the sward prevents any sudden diminution of absorbing root surfaces.

(4) The better physical properties of the soil developed under grass provide facilities for extensive root development and hence an efficient exploitation of the soil volume. A process producing the reverse effect may occur under clean cultivation in the absence of bulky organic additions to the soil.

(5) The demand for soil moisture made by the sward decreases with ageing of sward and orchard because the water-exploiting powers of the sward decrease and the extending tree canopy reduces the exposure of the sward to sunlight and wind and increases the humidity, so reducing the transpiration losses from the sward.

A further factor may operate resulting in an increase in soil depth under a sward for it was noticed that after five years the soil depth under the sward had increased by 2 in. The occurrence of this effect over large areas such as a grassed orchard has yet to be confirmed.

As the different ' compensating factors ' develop and contribute their effects, each will serve to improve the soil moisture conditions under a sward. But the fact remains that throughout the growing season the grass roots will compete with the fruit crop roots for the available moisture in their common root zone and will give rise to a greater rate of drying of the soil than would occur in the absence of a ground cover of vegetation. In the end analysis, once a sward has ' aged ' the suitability of grass management for a given orchard soil must depend on summer rainfall and soil depth. If the full transpiration requirements of grass and trees in a grassed orchard had been met in 1952 a soil moisture loss of over 9 in. would have been sustained whilst the corresponding loss in 1954 would have been only 4 in. Hence it is clear that while 18 to 24 in. of soil would have sufficed to provide the transpiration requirements of a grassed orchard in 1954, twice that depth of soil would probably have been inadequate in 1952. Where soil depth or texture seriously limits the available moisture a soil can hold, either tree mulching or irrigation should be considered in conjunction with the grassing down of fruit crops.

Mulch

The moisture conditions under the straw mulch system of management suggested that on many soils the full moisture requirements of fruit crops could be satisfied. Serious consideration should be given to the use of mulches or partial mulches where soil moisture depletion is a seasonal problem. The entire moisture reserves are retained for crop use and, in addition, the topsoil is made available to crop roots and maintained relatively moist because a mulch permits free entry of rain into the soil and retains it there against evaporation.

During the period of the study the total amount of wheat straw applied as a mulch was equivalent to 28 tons per acre. Most of this decomposed and either was lost by oxidation or became an integral part of the surface layer of soil. Analyses showed a slight decrease in the organic matter of the mulched soil at the end of the experiment which means that there was a high total loss of organic matter from the mulched soil ; this loss might have been considerably reduced had a nitrogenous fertilizer been applied. However, the high rate of breakdown would lead to a high rate of mineralization of nutrients contained in the straw and this would probably account for the increased amounts of available potassium and phosphorus in the mulched soil. The distribution in soil depth of these nutrients was probably due to the considerable leaching which the mulch permitted. An increase in available potassium appears to be a general characteristic of mulches including cinders and glass wool, and is not confined to straw or other organic materials. In this study the level of available potassium in the mulched soil was considerably higher than could be accounted for by the potassium in the straw and was sufficiently high to justify the omission of this nutrient from the fertilizer programme for mulched fruit orchards. Apart from this important effect on the availability of nutrients, mulching may also affect nutrient absorption by roots by its influence on soil moisture. Mulching tended to depress slightly the available magnesium content in the soil ; in view of the high amount of through-drainage that occurred under the straw it seemed surprising that the losses of magnesium were not higher than those from the other two management treatments.

The stable crumb content of the mulched soil was inferior to that under the sward but considerably better than that of the cultivated soil. Since the conditions of non-cultivation and protection against raindrop impact afforded by the mulch were similar to those afforded by the sward, the more stable structure under the sward would appear to be a direct effect of the higher organic matter status of the soil (including both living and decaying organisms) enhanced possibly by the wetting and drying cycles experienced with sward management. The structural conditions under the mulch were not all that could be desired : there was a tendency towards surface compaction which, together with the very moist conditions, gave rise to localized regions of poor aeration. In the presence of a crop and the absence of heavy traffic this danger would be lessened but the symptoms of impaired aeration have indicated a potential danger of permanent mulches especially on ' tight ' soils. A possible remedy lies in the incorporation of the mulch occasionally followed by the addition of a fresh layer of mulching material. It would be most unfortunate if this feature were to detract from the use of the mulch, for in other respects this cultural method confers considerable benefits and, in the drier parts of the country, probably affords the greatest productivity potential from a soil. For this reason, it is to be regretted that in some fruit growing areas the limited amounts of suitable mulching material must severely restrict the commercial application of this practice unless growers are prepared to produce their own mulching materials.

Recommendations

Clean cultivation as traditionally practised in the fruit orchard, though preventing soil moisture depletion by weed growth, may lead to a decrease in nutrient availability and ready breakdown and dispersal of soil crumbs. The minimum of cultivation is recommended unless soil friability, porosity and fertility are maintained by incorporating organic materials.

Permanent swards offer the greatest benefits from improved organic matter status and structural conditions of the soil but make a serious demand on soil moisture.

Straw mulch appears to offer considerable scope for improving nutritional and moisture conditions for fruit crops, but the structural conditions of the soil under a mulch are not all that could be desired. A remedy for this defect has been suggested.

Summary

The effects on various soil properties of the three cultural treatments, clean cultivation, straw mulch, and grass and clover sward, all without fertilizer applications and in the absence of a crop, have been very marked. These effects have been discussed with reference to their possible influence on fruit crops.

HOW SPRAY CULTURES ASSIST THE STUDY OF APPLE NUTRITION

By ANNE V. DELAP and ELSIE M. FORD

It is necessary to assess as accurately as possible how fertilizers affect growth and cropping before they can be efficiently used. Field experiments can supply some of the answers but soils can ' lock up ' part of the applied nutrient so that it is difficult to determine how much of it actually gets into the tree. The effect of a certain amount of a fertilizer is therefore largely unpredictable, and depends on the type of soil and its past treatment. These factors also influence the nature and amount of the nutrient reserves in the soil. It follows that the results of a field experiment cannot be applied to the whole range of fruit soils, but only to soils similar to that in the experiment, unless detailed knowledge is available of the way in which the different soils affect the results.

More exact control over the nutrient supply can be obtained by growing the trees in water, to which the various nutrients have been added, and this method also has the advantage that the trees can be weighed at intervals and many other detailed records taken during the experiment.

As a beginning, experiments have been done on very simple fruit plants, one-year-old layers of an apple rootstock, but later on it may be possible to work with fruiting trees. It is difficult to grow these layers in water culture because their roots need very well aerated conditions. For this reason Dr. W. A. Roach decided to suspend the plants with their roots in air and to spray the nutrient solution on to the roots. This method was successfully used for detailed experiments in the four years, 1953-56.

Large containers were made, with close-fitting lids provided at the circumference with a circle of special holders. In these M.VII rootstocks were put, so that their roots hung down in darkness inside the containers, which were partly sunk in the ground to help to keep them cool. In the centre of the lid was a small horizontal disc, kept spinning at high speed by an electric motor. A solution of nutrients dripped steadily on to this disc and was flung off by centrifugal force as a fine spray which kept the plant roots constantly wet. The rate of flow of nutrients to the disc was controlled by an automatic device and the kind of nutrient solution supplied to each container could be altered at will.

The effects of iron and magnesium on growth were studied, since deficiencies of these elements often occur in orchards, and they are particularly difficult to study in field trials. Four nutrient solutions were used : (1) complete, (2) very low in iron, (3) very low in magnesium, and (4) low in both iron and magnesium.

The plants grew in the containers throughout the summer and it was possible to learn something about the way in which the deficiencies were affecting them by taking detailed records of the increase in their weight and the growth of their leaves and shoots. The symptoms which developed on the leaves were very similar to those found on orchard trees suffering from iron or magnesium deficiency, even though, in the spray culture, the lack of iron was an absolute one, while in the orchard iron deficiency is caused by lime in the soil which ' locks up ' the iron, in spite of an abundant supply of it. The first sign of iron deficiency was a paleness of the young leaves, which, as they unfolded, showed a pattern of dark veins on a light green background. Successive leaves were more and more pale until they were almost ivory white. Magnesium deficiency showed itself first as small purplish areas between the veins of some of the lower leaves. These soon developed into light brown dead patches and the leaves fell off. The symptoms spread rapidly up the shoot and by the end of the season almost all the leaves had been shed.

Besides producing typical symptoms on the foliage the deficiencies affected the growth of the whole plant. Iron shortage caused an overall reduction so that at the end of the season the shoots were shorter, the weight of roots produced was less, and the stems were thinner than those of the plants getting a complete nutrient solution ; the small amount of new plant material that had been formed had been shared out among the different parts of the plant in just the same way as in the much larger plants that were not deficient.

Shortage of magnesium also reduced growth, but in this case the new plant material was not shared out in the same way as in the healthy plants. Although elongation of the shoot was only slightly impaired, thickening of the shoot was much less than normal and root growth was very poor indeed. The result was that the amount of root in proportion to the amount of shoot was very much less in these plants than in the normal ones. Severe magnesium deficiency in the orchard may also have a particularly bad effect on the root systems of the trees, and this may partly explain the slow response of such cases to soil applications of Epsom salt.

The increase in the weight of a growing plant is almost entirely brought about by the leaves, the factory in which the raw materials of the plant are produced by means of the green colouring matter, chlorophyll. If the rate of increase in weight of a plant is compared with the area of its leaves, we have a guide to the efficiency of its leaves as a factory. When the iron deficient plants were compared with those receiving iron they were found to be much less efficient in this respect ; this is not surprising since the leaves of such plants contained very little chlorophyll and to this extent lacked the machinery for making raw materials. When magnesium was deficient the reduction in the efficiency of the green leaves was not as great, but in these plants the leaves were apparently just as green as those of the normal plants until the time when they became scorched and fell off. It was probably this decrease in the number of green leaves which reduced the growth of these plants.

From the growth records and symptoms something can be learned of the probable movement of iron and magnesium in the plant. Thus, the first few leaves formed on the iron deficient plants were a normal dark green and must therefore have had enough iron ; young leaves farther up the stem were yellow owing to lack of iron. This state of affairs continued throughout the season so that it would seem that no iron was removed from the older leaves to supply these younger ones. This supports the general opinion that iron does not move readily from one leaf to another. Magnesium, however, appears to be relatively easily moved from one part of the plant to another. The older leaves near the base of the stem developed symptoms of magnesium deficiency and fell off while the young leaves were a healthy green. Even when the symptoms had become very severe the apex of the stem was still growing in length and unfolding apparently healthy leaves, suggesting that magnesium may have left the basal leaves and moved to the tip of the shoot. That more magnesium may have been available at the tip of the shoot than at its base is also indicated by the fact that, while growth of the tip was proceeding nearly normally, thickening at the base of the shoot was very slow, suggesting that growth of the cambium was being impaired by lack of magnesium.

Another point of practical importance that is shown by this work is that plants need a steady supply of magnesium. At the beginning of the experiment all the plants were grown for a time in a nutrient solution to which neither iron nor magnesium had been added, so as to use up some of the reserves of these elements stored in the plants. Before any symptoms of deficiency had appeared the four treatments were applied ; from this moment the plants receiving the complete nutrient solution had ample magnesium, yet symptoms of mild magnesium deficiency began to appear on a few of their leaves four weeks later. It seems that, even if a deficiency of magnesium is corrected before the symptoms are showing on the leaves, symptoms may subsequently appear on some of the leaves which were formed under conditions of shortage. This may explain why, when an orchard is being sprayed with magnesium sulphate to cure deficiency symptoms, sprays have to be applied early in the season (petal fall) and must be repeated often (at least five times) at fortnightly intervals if symptoms are to be completely suppressed. If the first spray is not put on in time some of the leaves may later develop symptoms and if spraying is stopped too soon, while the shoots are still growing, magnesium will be drained away from the lower leaves by the developing tip and symptoms may appear.

Summary

The effects of iron and magnesium deficiencies on the growth of rooted layers of apple have been investigated by spraying their roots with nutrient solutions. The results are briefly described and discussed in relation to orchard practices.

PROGRESS IN RESEARCH ON VERTICILLIUM WILT AND VIRUS DISEASES IN HOPS IN 1957

By R. V. HARRIS

This is a review of items of special interest to hop growers in the general research report of the Plant Pathology Section for 1957 (p. 22).

Progressive Verticillium Wilt

New wilt-tolerant varieties

As forecast last year health-tested stocks of two new wilt-tolerant hops, D1 and D3, bred at East Malling by Dr. W. G. Keyworth were released in the autumn of 1956 to the Propagation Committee of the Hops Marketing Board to be allocated to commercial specialist hop propagators for multiplication and supply to growers under the A-Plus Certificate of the Ministry of Agriculture, Fisheries and Food. This was followed last winter by a similar decision on yet another wilt-tolerant hop, J2. The decision to release these three new varieties for general cultivation by hop growers in the wilt-stricken areas was taken on the favourable results of wilt-tolerance, cultural and brewing trials made over the past five years to meet the urgent need of growers for replacements for the unacceptable Keyworth's Mid Season hop (OR55).

Full descriptions of the D1, D3, and J2 hops are being prepared for publication in the Station's Annual Report for 1958.

Health-tested stock of wilt-tolerant varieties

In addition to putting out these three new tolerant varieties, East Malling also released last winter from its gauzehouses for commercial propagation comparable health-tested stocks of the Wye variety Bramling Cross (OT48) and of two wilt-tolerant male hops which, with a third male to be issued from Wye College, will provide complete seasonal coverage for gardens of the new wilt-tolerant varieties.

How wilt-tolerance works and its limitations

Before it can cause the death of a sensitive hop plant such as Fuggle the progressive variety of the Verticillium fungus causing hop wilt (*Verticillium albo-atrum*) has not only to penetrate into the roots but into the water-conducting strands making up the circulation or ' vascular ' system of the plant, and then find its way in quantity up into the upper reaches of the bines, laterals, and leaves.

Two defence mechanisms which tend either to prevent these breaks-through or hinder the upward progress of the invader have been discovered in the course of our research. Last year (1956 Report) we reported on further work on one of them, namely the balloon-like obstructions, or *tyloses*, which are formed in the water-conducting tubes ahead of the advancing fungus. The fact reported then that these tyloses are also produced in response to other causes such as mechanical wounding of the bines suggests that this mechanism has not been specially developed by the hop against *Verticillium* and therefore cannot be expected to do more than slow down, rather than halt, the upward progress of this fungus.

The other defence mechanism is located in the sheath of cells surrounding the water-conducting or ' vascular ' strand at the core of hop roots, known as the *endodermis*, or endodermal layer. In tolerant varieties the progressive wilt fungus advancing from its point of entry into the root is generally seen to be halted at this layer and thus to be prevented from entering the vascular system and causing wilt.

Further research in the year now under review suggested a likely explanation of this defensive action of the endodermis. It now seems probable that this depends on the capacity of the tolerant variety to deposit on the walls of the endodermal cells, ahead of the advancing invader fungus, a layer of a waxy substance called *suberin*, and this the fungus cannot penetrate. If this explanation is confirmed then it would seem unlikely that we can expect the endodermis always to act in this way because it is only in the older parts of the roots, behind the root-tips, that such layers of suberin can be formed, and the fungus could therefore break through into the vascular system if it attacked sufficiently near the root-tips. Such successful penetrations in tolerant varieties have in fact been observed and this further explains why a certain amount of wilt does in fact occur in tolerant varieties. It would

therefore seem unlikely that one hundred per cent tolerance, let alone immunity, can ever be expected in new varieties of this kind.

For this reason, and because, as was discovered earlier, the fungus always appears able to invade the rind of the roots of even tolerant varieties, it would clearly be unwise and imprudent to put all our hopes on these varieties for the ultimate conquest of Progressive Wilt and neglect the other approach to its control, namely, measures for destroying the progressive fungus in the soil and its various other hide-outs. In other words we should clearly offset a policy of ' containment ' of the fungus in the tolerant varieties by a drive for direct control aimed at reducing its population in the soil of the wilt areas and in other host plants such as annual weeds, and at stamping out new outbreaks outside these areas at birth. Prevention is better than cure.

The survival of the progressive Verticillium fungus in the soil

Conidia-spores and survival.—The habit of this fungus, mentioned last year, of passing into the soil from infected hops as minute thin-walled conidia-spores instead of penetrating the soil with the usual fungus threads or filaments (mycelium) was confirmed this year by direct observations of the process, in special little glass-walled boxes, through the microscope. This habit suggests that the wilt-fungus is not ' at home ' and is therefore especially vulnerable in the soil, and it now remains to discover in detail the capacity of these conidia in the soil to survive, germinate, and re-infect hop roots.

Infection from dead bine and from conidia-spores compared.—In an experiment this year Fuggle plants wilted more rapidly when inoculated with infected bine than with conidia spores. The highly tolerant Wye variety OM26 was also used in this experiment and however this was infected, whether by bine or conidia-spores, no symptoms of wilt developed. The wilt-fungus, however, was found in more than half the bines of these plants, thus proving how a tolerant variety may act as a symptomless carrier of this disease.

The effect of planting tolerant varieties on the survival of the fungus in the soil.—When a wilted garden is grubbed and replanted immediately with a wilt-tolerant variety does the soil become progressively less capable of infecting and causing wilt in hop plants ? A large-scale field experiment on a commercial farm where Whitbread's Golding Variety (1147) has been planted after wilted Tutshams was started this year to answer this question.

The effects of various cultivation programmes on the survival of the fungus in the soil.—This field experiment was planted in winter 1955-56, to compare the survival of the fungus in heavily infected soil under (*a*) bare fallow with and without a grass mulch, (*b*) weed-free grass, and (*c*) an annual weed ' tumble-down '. This year the soil was sampled for progressive Verticillium fungus after its first year under these treatments, but it would be premature to discuss the results that are emerging now.

Meanwhile, two further large-scale trials on the same subject have been established. One at the Research Station aims to compare weed-free grass cover with annual weed tumble-down under conditions more closely approximating to those of the commercial hop garden. The other, in a commercial garden newly grubbed from Progressive Wilt, is designed to try out a weed-free grass cover on the survival of the fungus.

The wilt-fungus in weeds

That common annual weeds in hop gardens can harbour the progressive wilt fungus was finally proved this year when six samples of the fungus Verticillium found in groundsel, fat-hen, annual nettle and black nightshade collected from wilt gardens were tested on Fuggle against standard samples of the progressive and fluctuating varieties of this fungus. In all six cases the Fuggle developed typical Progressive Wilt.

The bearing of this discovery on the drive for direct control of the fungus before it can infect the hop plants is not a simple one to answer. Should clean cultivation be extended throughout the growing season, or is it possible that by doing this, infection may be spread by the movement of infected weeds on cultivators, or even that the hop-infecting power of the progressive fungus in hop garden soil may be less in soil carrying a vigorous annual weed mat ? These questions which are clearly subjects for further research are discussed elsewhere in this Report in the light of the facts already known (p. 126).

Hop virus diseases

Nettlehead

Following up the idea put forward in last year's Report that Nettlehead might be caused by a virus primarily based in weeds, we succeeded this year in passing a virus from a nettlehead-infected hop to clover by bridging the two plants with the parasitic plant dodder. This virus was then successfully passed from the clover back to hop seedlings by means of a species of leaf-hopper. It

seemed therefore more than possible that Nettlehead is caused by a virus naturally occurring in clover and this idea was further tested this year by other experiments. As the results of the latter are not yet available we will return to them in next year's report. Meanwhile the possibility of spread through the soil is also being followed up.

The suggestion that Nettlehead might be caused simply by overdoses of nickel and other heavy metals from the soil was disproved by critical experiments this year. It seems more likely that the abnormally high quantity of nickel undoubtedly found in nettlehead plants is an effect, or symptom, of their infection with nettlehead virus.

Mosaic Disease

Work to determine the natural agents of mosaic spread this year was directed more particularly to species of mites found on plum at the time of the spring migration of the common Hop-Damson Aphid.

Split Leaf Blotch

Field experiments this year have shown that this disease has a bigger depressive effect on crop than was originally suspected. What we still lack in working on it is a satisfactory 'indicator' plant which we can rely on always to show the presence of the virus in suspected plants. Meanwhile we are making the best use of Fuggle N in this respect for assessing the reactions of several new varieties to this important disease.

Summary

Matters of special interest to hop growers in the Station's Report of research in 1957 on Progressive Verticillium Wilt and the virus diseases Nettlehead, Mosaic, and Split Leaf Blotch are reviewed and discussed.

PROGRESS IN RESEARCH IN FRUIT CROPS IN 1957

By H. B. S. MONTGOMERY

The following notes are intended to serve fruitgrowers as a guide to some of the items of more immediate practical interest in Part II of this Report, in which the progress of research during the past year is reviewed.

Frost damage

The combination of an early blossom season, late spring frosts and poor fruit-setting conditions led to poor crops and upset some experiments. The frost on the night of 5th-6th May did, however, provide excellent conditions for many observations on the susceptibility of different varieties and kinds of fruit. On the Frost Plot, the minimum temperatures were 28° F. in the screen and 22° F. on the grass ; injury was severe on all fruits but the following carried some crops : Bristol Cross pear, Pershore plum, Crawley Beauty, Laxton's Superb and Edward VII apples, Frogmore cherry, Cambridge Rearguard and Vigour strawberries, and black currants in general owing to their advanced stage and the shelter provided by the foliage. Injury to gooseberries occurred mainly with Leveller and Green Gem.

In recent years much work has gone into the development of an automatically controlled system of water sprinklers to combat frost. This year a range of sprinklers, covering about $\frac{1}{4}$ acre, were turned on automatically whenever the temperature fell below 32° F. ; this resulted in a full crop on the trees protected in this way, whereas those outside the sprinkled area bore nothing.

Under artificial conditions, the effects of water supply, nutrients, and prefreezing temperatures on the resistance of blossoms to damage have been studied and further information is being gained from microscope studies of the way in which ice forms in relation to frost resistance.

On higher ground, where temperatures were about 1° F. above those on the Frost Plot, plums were particularly severely affected, but 19-year old trees of Severn Cross gave 170 lb. per tree compared with 30 lb. from Marjorie's Seedling, Bountiful, and President of about the same age. In the gage trial those that cropped appreciably were Comte d'Althann's Gage with 100 lb., Warwickshire Drooper with 70 lb., Victoria with 40 lb. and Ontario with 30 lb. per tree.

An unusual feature this year was the absence of frost blemishes on Bramley's Seedling and Howgate Wonder ; Tydeman's Late Orange was severely blemished with a deep corky russet.

Rootstocks

Apple

The new rootstock, MM.104, has shown such good root anchorage in the trials at East Malling, that there is a possibility that staking may be unnecessary even during the first years after planting. Accordingly a trial of Cox's Orange Pippin on M.II and MM.104 has been planted on a windswept site on a farm in Sussex, comparing trees staked at planting with others left unstaked. After seven years the stakes will be removed from the staked trees and further records will be taken to see if they are any less securely anchored than those that have never been staked.

Cherry

The new rootstock and cultural trial in Newgates Field includes Merton Bigarreau, Merton Glory, and Géante d'Hedelfingen on the vigorous mazzard F 12/1, and on F 1/3, which has proved much weaker in nursery trials. In subsidiary trials with Early Rivers, F 12/1 is compared with F 5/4, of moderate vigour, and bush trees with a stem of 3 feet are compared with normal 6 ft. standard trees. These new trials occupy 10 acres and are interplanted with Victoria plum on Myrobalan B and Brompton, and high- and low-worked Ontario on Myrobalan B. After the first five years, different soil management systems and fertilizer treatments will be superimposed, and the plum trees will eventually be removed when the cherries need extra space.

Plum

Oullins Golden Gage usually exhibits incompatibility on Myrobalan B, trees breaking off at the union at all ages. A trial using two other Myrobalans, Wibaut's (from Belgium) and 29 (from U.S.A.), as well as Myrobalan B, showed that the only rootstock providing a union that resisted breaking at two years old was Wibaut's Myrobalan.

New pear plantings

For many experiments it is valuable to have young trees grown under uniform conditions for several years before any special treatments are applied. Some trees grow more strongly than others even when they are of the same variety and rootstock and are treated alike ; these differences can be recorded during the early years and the results used to improve the accuracy of the subsequent experiment. An example of such a ' calibration area ' is the 2½ acres of pears at 15 × 15 ft. spacing just planted. The main varieties are Conference and Williams' Bon Chrétien, and in the guard rows other varieties are included, Laxton's Superb, Packham's Triumph, Bristol Cross, Gorham, and Doyenné du Comice. All the trees are on Quince A but Williams', Packham's, and Bristol Cross are double shield budded with Beurré Hardy as the intermediate. Alongside this calibration area, a plot has been planted with Comice, Conference, and Hardy on Quince A for the study of pruning methods to secure early and regular bearing.

Propagation

The hardwood cutting method, based on the hormone treatment and winter storage of cuttings from specially grown hedges, has proved successful with the apple rootstocks M.II, M.VII and MM.104 and the plum rootstocks St. Julien A and Pershore, in addition to the rootstocks used in the original experiments.

A further season's experience has been gained with leafy cuttings under intermittent mist and the main problem now under investigation is how to avoid heavy losses when the rooted cuttings are transferred to the open nursery.

Soft fruits

Strawberry

The virus tested clones of Huxley and Perle de Prague, that were freed from virus diseases by heat-treatment by the Pathology Section, have continued to crop better than the original clones. The heat-treated clone of Cambridge Favourite, though still known to be carrying a mild virus, was more vigorous and cropped more heavily than the untreated. In the case of Early Cambridge and C. Rearguard the treated clones yielded much less than the untreated ones owing to fewer blossoms being produced on these excessively vigorous plants.

A new clone of Royal Sovereign M.415, selected from plants from Ireland, has been compared with the present Special Stock clone M.48 for a number of years. It shows no differences from M.48 either botanically or in the appearance or flavour of the fruit but it has cropped on average some 15 per cent more heavily. In this season the yield was over 40 per cent greater, most of the increase being in the main and later picks rather than in the earlier ones. It has, therefore, been decided to release this new clone, and plants have been supplied to the Nuclear Stock Association.

Cane fruits

The five new selected Loganberry clones carried their first crop, and four of them gave as heavy crops as had been recorded for the best selection in the pre-war trials.

Three raspberry variety trials were concluded at the end of 1956. In two of the trials the Malling seedlings Promise, Exploit, 51/47, and T gave the best crops with averages of over 70 cwt. per acre compared with just less than 50 cwt. for Norfolk Giant and Newburgh. Of these seedlings 51/47 is difficult to pick and inferior to its sister variety Malling Promise. The yield and quality of seedling T make further trial with it desirable. The New Zealand Lloyd George slightly out-yielded the Amos clone during the first six years, and also Promise and Exploit, but much of the fruit of Lloyd George was too small and crumbly owing to virus infection to be of commercial quality.

Weed killers

The control of weeds in soft fruit plantations involves considerable labour and is therefore costly. There are a number of chemicals that are effective against certain of the important weeds but little accurate information is yet available on their effects on the growth and cropping of the fruit plants. Special attention is now being given to these effects.

On strawberries, 2,4-DES applied at 3 lb. per acre monthly during the summer, with DNBP amine at 2 lb. per acre in the autumn gave satisfactory weed control without causing appreciable damage to Royal Sovereign plants.

On black currants, MCPB is being tried at 2, 4, and 8 lb. per acre after picking ; similar treatments are also under trial with raspberries.

Interpretation of experimental results

The results of most experiments are recorded in figures that separately refer to growth, blossoming, cropping, etc., and no simple method has existed for bringing these separate records together so that the plant as a whole may be considered. Some of the methods used in other investigations do, however, appear promising when applied to data from fruit trees. Thus in psychology, *factor analysis* is used to combine a number of related measurements, and in anthropological research, *discriminate analysis* is used in studying the relationship between tribes, castes, etc., by means of measurements of bones from graves of known origin. Factor analysis has been used recently in calibrating trees (see p. 87) to help in deciding whether to use trunk girth or previous crops to estimate present cropping. *Discriminate analysis* has proved helpful in one of the long-term rootstock trials in bringing together various measurements of growth to assess vigour ; in the past a different estimate of vigour could be obtained from, for example, girth increases, extension growth, and height and spread.

Carbohydrate reserves

The growth and fruiting of plants depend ultimately on the manufacture of carbohydrates (sugars, starches, etc.) in green leaves in the presence of light ; this process is known as photosynthesis. Some of the carbohydrates produced in this way are not used immediately for growth and fruit but are stored away in various forms in the trunk, branches and roots ; little is known about what happens to them subsequently or their importance to the tree. As part of a long-term study of this problem, a series of six year old apple trees is being grubbed at monthly intervals and samples of bark and wood are being analysed for these ' reserve carbohydrates ' in the hope of shedding light on this problem.

Nutrition

The long-term manurial trial with Cox's Orange Pippin on M.XII has given some very interesting results on the effects of grassing down ; this took place on certain plots in 1953. Where the grassing down was accompanied by annual dressings of 6 cwt. per acre of sulphate of ammonia there has been no reduction in cropping but in the absence of the nitrogen the crops have been lower than under arable conditions, in spite of the fact that the sward has been rich in clover where nitrogen has not been applied. Fruit colour and storage life as indicated by rots and breakdown have been better on the grass plots, even where nitrogen has been applied ; it is thus possible to improve fruit quality by a grass sward without necessarily losing crop in doing so. A detailed grading of the fruit from each tree was undertaken this year but the results are not yet available.

The trial of magnesium sulphate, applied as 2 per cent sprays at fortnightly intervals, on Edward VII on M.VII has now been running for four years. Over this period five post-blossom sprays each season have resulted in an increase in the total crop of 50 per cent compared with that of the untreated trees. This crop increase was accompanied by an absence of leaf scorch until late in the season but there was no increased growth. It is rather surprising that so large an effect has been obtained because the soil is not unduly low in available magnesium nor is the availability complicated by a very high level of available potassium ; both Edward VII and M.VII are, however, very susceptible to the deficiency, judging by the severity of the leaf symptoms produced. Sprays of urea (0·5 per cent) also gave an increase in crop, which was not so great as that caused by the magnesium sprays, but they had no effect on leaf scorch. This result may be due to a reduction in the drop of fruitlets.

The good effects of nine sprays of Epsom salt on stoolbeds of M.IV and MM.102 suffering from magnesium deficiency are described in a paper on p. 106. In addition to improved growth, the number of shoots affected with Apple Mildew was reduced by the sprays compared with the number of infected shoots where only water and wetter were applied ; this reduction, however, did not represent a commercial control of the disease. It is not yet clear whether the effect is due to a reduced susceptibility of the stocks by curing the deficiency of magnesium or to the magnesium sulphate acting as a fungicide. It is too early in this work to base any recommendations on it.

Some of the effects of soil management on moisture and nutrient supplies in the soil are discussed in a paper on p. 113. In a new raspberry trial that was planted in 1956, supplementary water gave increased growth and berry size in 1957.

Manurial trials on black currants at East Malling have not in the past given conclusive evidence on the relative value of different nitrogen applications, possibly because of the deficient supply of water at crucial times of the year. A trial has now been started where different soil moisture conditions are being compared at two rates of applied nitrogen. Although the trial was planted as recently as November 1956 and an overall watering was given in May to help the bushes to become established, records taken in September showed that the experimental watering begun in July had noticeably affected growth.

Mineral composition of fruit trees

Information is gradually being accumulated about the chemical composition of fruit trees. Thus in January 1957, when an orchard was being grubbed at East Malling, parts of the roots, trunk and branches of a 40 year old Cox's Orange Pippin tree were taken and analysed.

The tree had a girth of $33\frac{3}{4}$ in., weighed 974 lb. and contained 462 lb. of free water in the fresh tissues. Analysis showed that the total nitrogen and potassium present were equivalent to about 11 lb. sulphate of ammonia and about 3 lb. sulphate of potassium respectively. Assuming that 40 lb. of wood and 100 lb. of fruit were removed annually it is calculated that nitrogen and potash equivalent to about 1 lb. sulphate of ammonia and $\frac{1}{2}$ lb. sulphate of potash must be made good every year. The gross amounts of these elements required by the tree during the growing season were undoubtedly much greater on account of leaf production but the nutrients would eventually have been returned to the soil. Compared with the amounts of nitrogen and potassium applied to the soil, the amounts of these elements built into the permanent structure of the tree and lost from the orchard in crop and prunings is quite small ; the rest is probably necessary to ensure adequate concentrations of these nutrients in available forms in the soil.

Bacterial diseases

Further field trials of the antibiotic streptomycin for the control of Bacterial Canker have confirmed the indications of previous years that streptomycin is no more effective than the conventional spray materials colloidal copper and Bordeaux mixture. Furthermore, it had proved simple to build up strains of the bacterium, *Pseudomonas mors-prunorum*, resistant to streptomycin by growing it in the laboratory in broth cultures with increasing amounts of the antibiotic. The field use of streptomycin might be expected, therefore, to lead to such resistant strains being developed. Strains resistant to copper are unlikely to develop. The value of early autumn sprays against this disease was again shown.

Fungal diseases

Further trials of cinnamic acid applied by low volume spray at 0·2 per cent in a greenhouse confirmed that it was effective against both Apple and Pear Scab. Work has also been done on o-coumaric acid, another chemical related to the naturally occurring caffeic acid, and the indications are that it will prove even more active than cinnamic acid.

It seems that *Phytophthora cactorum* may be causing damage in orchards apart from the obvious death of trees by Collar Rot, because it can attack the fine, fibrous roots of susceptible varieties and check their growth. Work is in progress to find which of the existing rootstocks are resistant to this fungus.

Silver Leaf is still one of the most serious troubles of plum growing, and in spite of care in pruning and general management, too many trees become infected early in their lives. The need is for a direct curative treatment that could be applied to an infected tree, and towards this end, 8-hydroxyquinoline potassium sulphate and other chemicals are being injected into artificially infected young plum trees. At present any checking of the disease is only temporary, and the effect of the treatment is difficult to measure because the growth of the fungus appears to be affected by the hole drilled in the trunk for the injection.

In the second season's spray trial at Horsmonden against *Gloeosporium* rots, a captan spray in September gave better control when preceded by a similar spray in August. This result is in contrast to the result last year when the August spray added little to the effect of the September one ; obviously the occurrence of certain weather conditions, probably rain, in relation to the time of spraying is of great importance. A preharvest spray of cinnamic acid was compared with a dip of the same chemical after picking but the results are not yet available.

There is an urgent need to find an efficient safe fungicide against Apple Mildew. Greenhouse and field tests have shown that up to the present lime-sulphur and DNOPC (Karathane) are superior to all other materials. The search for new chemicals and the possible improvement of existing ones by the use of wetting agents continues, using special testing methods in a greenhouse. In developing these methods it was confirmed that the most susceptible leaf on a shoot is the youngest ; it is inevitable, therefore, that very frequent applications of suitable spray fluids are needed to protect these leaves as they unfold. In a field trial early spring sprays were again shown to have little effect in controlling mildew ; the important sprays are those that come after blossom.

Virus diseases

The number of viruses recognized on top fruits is increasing steadily, and an important part of our research is the search for suitable indicator plants that produce clear symptoms when infected. Most

fruitgrowers are, however, mainly interested in how much growth and cropping are reduced by the commonly occurring viruses, and several new trials have been planted to determine this. Thus with apple, the effects of rubbery wood, mosaic, chat fruit, and starcrack viruses are being tested on four dessert varieties ; and with plums, prune dwarf, line-pattern, bark split, ring spot, and stunt viruses are being tested, on four varieties also. With cherries, the trial was planted in 1953 and the 1957 crop of Merton Bigarreau and Napoleon was reduced by infection with necrotic ring spot, necrotic line-pattern, and rugose mosaic viruses.

Certain trees of Waterloo and Black Elton cherry in the West Midlands were observed to be bearing small bitter fruit in 1955, and in the two following seasons. This condition resembled a serious virus disease known as Little Cherry in British Columbia and scion wood from the affected trees was therefore grafted on to young cherry trees at the Research Station. These have now developed typical symptoms and the disease is therefore due to a graft-transmissible virus. So far there has been no evidence that the disease is spreading in the West Midlands (see p. 122).

The collection and testing of varieties for distribution in the Mother Tree Scheme continues ; where no healthy material has been found, heat treatment followed by propagation from the tips of young shoots is being tried. So far all attempts to get healthy scions of Roundel have failed.

With soft fruits, the work on strawberries has been concerned with the transmission of green petal virus in the field and with sorting out the relationship of this virus to *Rubus* stunt, hop nettlehead and potato witches' broom. A new disease, ' Yellow Crinkle ', causing severe symptoms on Huxley, Cambridge Favourite, Deutsch Evern, Mme. Lefebvre, and Cambridge Vigour has been found. This appears to be quite distinct from the familiar Crinkle disease of Royal Sovereign and apparently is not transmissible by aphids.

Fourteen strawberry varieties, including for the first time Redgauntlet, Sir Joseph Paxton, Jucunda, and Cambridge Rival were propagated for 1957-8 issue to the Nuclear Stock Association.

The testing for virus of selected Loganberry clones continues ; all thirteen of those tested this year appear to be free from the virus obtained from ' degenerate ' plants. These selections are being compared in field trials for growth and cropping. Attempts are being made to transmit the virus from a degenerate plant by aphids and to measure its effects in the field on Loganberries.

Pests

As the Malling-Merton rootstocks confer no resistance or immunity to scions worked on them, though they are themselves resistant to attack by Woolly Aphids, there is obviously a need for resistant scion varieties.

The testing with Woolly Aphids of a number of seedlings from crosses between Court Pendu Plat and Northern Spy, Crawley Beauty, and Cox's Orange Pippin, revealed that except where Cox's Orange Pippin was a parent a proportion of resistant seedlings was produced. The crossing of Cox's Orange Pippin with Irish Peach produced fully susceptible seedlings.

The entomologists are also helping the plant breeders to select *Rubus* seedlings for resistance to the aphid, *Amphorophora rubi*, that is most important in transmitting virus diseases in raspberries. Over two thousand tests have been completed in the insectary and population studies made on selected seedlings in the field. A survey of Malling Landmark at many centres revealed that different strains of the aphid exist, one of which can live, but not thrive, on Landmark, a variety that is highly resistant to the normal strain.

The study of the Fruit Tree Red Spider Mite and its many predators continues to yield interesting results. Thus in the field trial of the combined effect of certain insecticides and fungicides, the prevalence of the Black-kneed Capsid referred to last year resulted in a very low population of the Fruit Tree Red Spider Mite this year. The Black-kneed Capsid was itself scarce this year and the position is similar to that when the trial started in 1953. The cycle of events is likely to repeat itself now, beginning with a rise in numbers of Fruit Tree Red Spider Mite next year.

In the insectary, an investigation was made of the ability of predacious mites, species of *Typhlodromus*, to check populations of Fruit Tree Red Spider Mites from building up. In some cases, the predacious mites were provided with an ample supply of another mite (*Vasates fockeui*) as an alternative prey.

Research is in progress to discover why *Bryobia* mites are increasing in numbers and becoming more common in commercial apple and pear orchards. It is now known that one strain of this mite persists throughout the year in unsprayed orchards and that the species on gooseberry (*Bryobia ribis*) differs from that on apple and has only one generation a year. *Bryobia* mites also occur on other top and soft fruit, hawthorn, and grasses and it is necessary to study them closely to find out how many species or strains are involved.

In connexion with the investigations on the persistence of spray deposits and their effects on pests

and predators, it has been necessary to evolve methods of rearing predators. This has entailed selecting a suitable food insect that is easy to rear, and also methods of cold storing leaves, shoots, and plants for it and other test insects to feed on. The eggs of predacious capsids and the winter eggs of red spiders have also been successfully stored to hatch up to nine months after the normal time or by suitable treatment their hatching can be speeded up by several months.

Satisfactory control of aphids, Apple Sucker and Winter Moth cannot always be achieved with a single application of DDT, BHC, DDT and BHC combined, or endrin according to the results of trials from 1951 to 1957, and observations on commercial farms. This failure is due to several causes, especially the different hatching periods of the pests and the failure to obtain complete cover of the leaves by current spraying methods.

Against Codling Moth, ryania, diazinon, DDT, and lead arsenate are being tested and the effects of these treatments on the Fruit Tree Red Spider Mite and leaf hoppers recorded. Leaf hoppers are being intensively studied, especially those species suspected of being concerned in the transmission of virus diseases of soft fruits.

In investigating the migratory nematode population of soil from a ' declining ' apple orchard, moderate heat (140° F. for 30-40 minutes) has been used to destroy the nematodes. This has resulted in increased vigour and root health of apple plants growing in the soil, and at first sight it would seem that the freedom from eelworms might be responsible for the improvement. In looking into this, however, a good soil with few nematodes was given the same heat treatment and it also gave a substantial improvement in growth after treatment. It is possible, therefore, that factors other than nematodes are also being affected ; these have been found to include mycorrhizal invasion of the roots and a property of the soil that checks the growth of fungi, but there are probably other factors not yet discovered.

Fruit storage

Cox's Orange Pippin apples from the long-term manurial experiment again showed the good effect of the sward treatment on keeping quality at 32° F. and 37° F., and that applied nitrogen led to a higher incidence of losses from rots and breakdown. Applied potash tended to increase rots but decreased breakdown. Established-spur pruned trees produced fruit that had fewer rots but more breakdown than fruit from more lightly pruned trees ; there was a tendency for the rotting to increase as the crop per tree increased. Grass sward also showed good effects on keeping with Laxton's Superb. This work is done in collaboration with the Ditton Laboratory.

The examination of over one hundred commercially grown samples of Cox's Orange Pippin after cold and gas storage failed to provide much support for these experimental findings ; this suggested that there may be more than one strain of Cox's Orange Pippin in cultivation or that various factors were affecting the nutritional level in the tree. The first of these possibilities is being explored by collecting scion wood from twenty-four selected sources and the second by collecting leaf samples for chemical analysis from thirty-two of the orchards during July. Samples of fruit from the same orchards were taken at harvest and will also be analysed.

Summary

Certain items of special interest to fruitgrowers in the reports of the Research Sections for 1957 are presented in popular terms.

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The current VOLUME 33 (1958) contains papers from both the sponsor Research Stations, from the John Innes Horticultural Institution, National Vegetable Research Station, Glasshouse Crops Research Institute, Scottish Horticultural Research Institute, Ditton Laboratory, Wye College, and the Grassland Research Institute. There are also papers from the United States and the Netherlands. The list of subjects is again very wide; of particular interest to fruit research are those on rootstocks, compatibility, the effect of radio-active phosphorus on stock/scion relationships, and also on its uptake and distribution in relation to the mutation rate in plants; the effects of various factors on parthenocarpy in apples and pears, root development in apples and black currants, nutrition, and a study of methods of restoring soil uniformity following the removal of mature apple trees. There are papers on raspberry viruses, loganberry cane spot and on the effects of post-blossom fungicides on apples. The Volume contains several papers on vegetable research, both in the open and under glass, notably on tomatoes and in relation to soil moisture; a device for the automatic control of day-length is described.

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